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Lathes and Lathe Work

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ENGINE LATHES
ENGINE LATHE TOOLS
LATHE PRACTICE
LATHE THREAD CUTTING
TURRET LATHES
TURRET LATHE PRACTICE

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PREFACE

The volumes of the International Library of Technology are made up of Instruction Papers, or Sections, comprising the various courses of instruction for students of the International Correspondence Schools. The original manuscripts are prepared by persons thoroughly qualified both technically and by experience to write with authority, and in many cases they are regularly employed elsewhere in practical work as experts. The manuscripts are then carefully edited to make them suitable for correspondence instruction. The Instruction Papers are written clearly and in the simplest language possible, so as to make them readily understood by all students. Necessary technical expressions are clearly explained when introduced.

The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for more congenial occupations. Usually they are employed and able to devote only a few hours a day to study. Therefore every effort must be made to give them practical and accurate information in clear and concise form and to make this information include all of the essentials but none of the nonessentials. To make the text clear, illustrations are used freely. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title are listed the main topics discussed.

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CONTENTS

NOTE.—This volume is made up of a number of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

TURRET LATHES

TURRET LATHE PRACTICE

ENGINE LATHES

CONSTRUCTION OF ENGINE LATHES

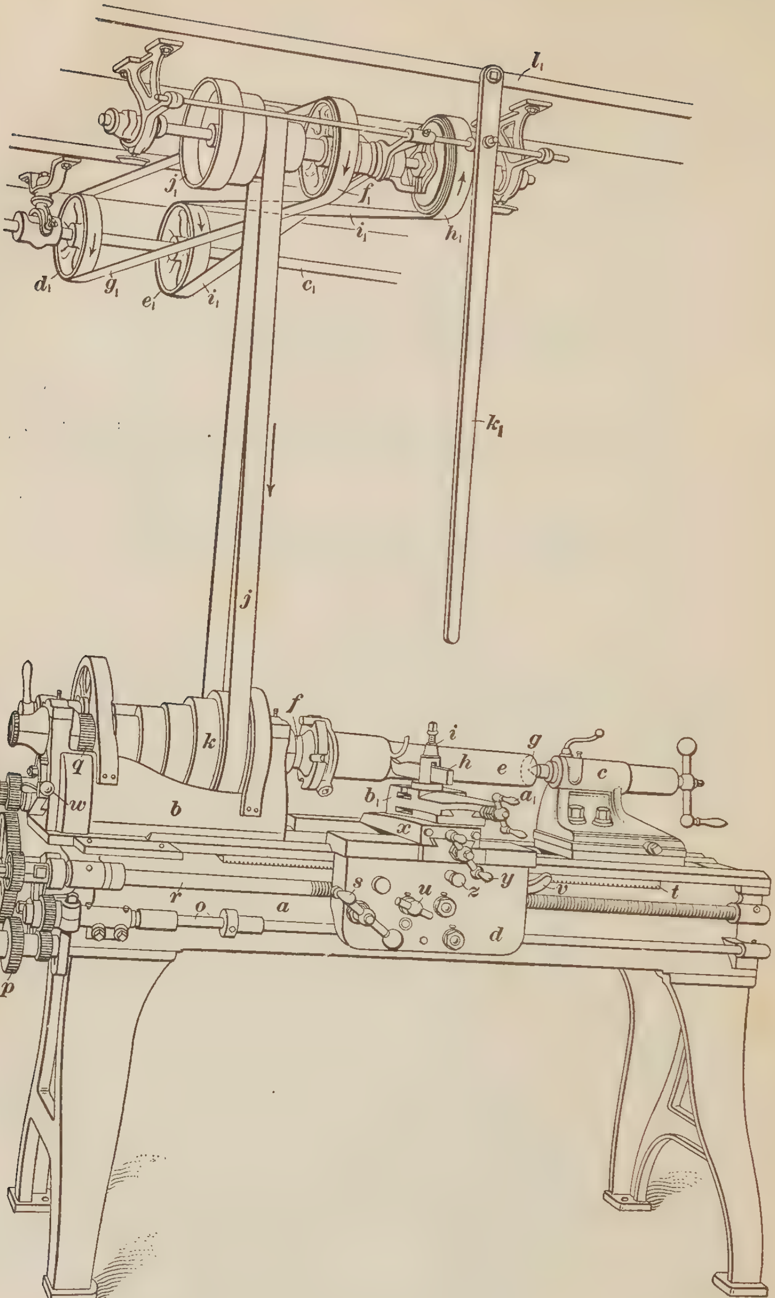
MAIN PARTS AND COMMON ATTACHMENTS

MAIN PARTS

1. Object of Engine Lathe.—The engine lathe is the machine most commonly used by the metal worker for turning, boring, facing, and threading operations. Its two special features are the power-operated movements of the cutting tool and the use of a lead screw for cutting screw threads.

2. Arrangements of Main Parts of Engine Lathes.—The construction of a typical small engine lathe is shown in Fig. 1. Its main parts are the *bed a*, the *headstock b*, the *tailstock c*, and the *carriage d*, which sets on top of the lathe bed and extends down the front. Long work *e* is held between the *live center* in the headstock spindle *f* and the adjustable *dead center g* in the tailstock; or the work *e*, if short, may be held in the jaws of a *chuck a*, Fig. 2, screwed on the headstock spindle. The cutting tool *h*, Fig. 1, is firmly clamped in a *tool holder i* supported on the carriage and may be moved either along the lathe bed or across it. The driving belt *j* rotates the cone pulley *k* and its spindle *f* and revolves the work.

3. A small cone pulley *l*, driven by a belt *m* from a similar cone pulley *n* on a stud at the back end of the headstock, drives the *feed-rod o* which moves the carriage along the bed,



l_1
j_1
f_1
i_1
h_1
d_1
g_1
e_1
i_1
c_1
k_1
j
f
i
g
k
h
e
c
q
n
w
b
b_1
a_1
m
x
s
u
z
y
v
t
r
o
a
d
l
p

FIG. 1

and with it the tool lengthwise of the work. Also, the feed-rod may be driven by using the gear *p* in the train. The belt drive will slip if the feed becomes excessive, and thus prevent damage. The three diameters on the cone pulleys *l* and *n* give three speeds to the feed-rod. The belt drive is omitted from the designs of lathes which are designed to use much heavier feeds than the lighter lathes, and speed-change gears are used instead of cone pulleys.

4. The train of gears shown on the end of the headstock is driven by a small gear *q* on the end of the cone pulley, and

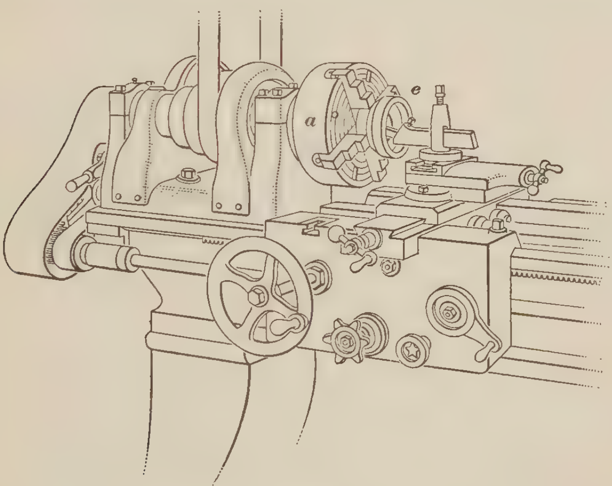


Fig. 2

this train drives the lead screw *r*, which moves the carriage when threads are being cut. The carriage may also be moved lengthwise by hand by turning the handle *s*, which revolves a gear that meshes with the feed-rack *t* fastened to the bed. The knob *u* is turned when the carriage is to be moved lengthwise by the feed-rod, and the handle *v* is thrown down when the lead screw is to be used. The lever *w* is for reversing the direction of the carriage motion.

The cross-slide *x* carrying the tool may be moved by hand by turning the handle *y*, or by power by pulling out the knob *z*.

The handle a_1 operates a feed-screw that moves the tool rest b_1 independently of the motion of the cross-slide x.

5. Overhead Drive for Engine Lathe.—The overhead drive consists of a line shaft c_1, Fig. 1, driven by the source of power, and carrying two pulleys d_1 and e_1. The pulley d_1 drives the countershaft pulley f_1 in the same direction by means of the open belt g_1, and the pulley h_1 is driven in the opposite direction by the cross-belt i_1. A cone pulley j_1 operates the belt j that drives the lathe. A wooden shipper k_1 is suspended from the hanger plank l_1 and reaches down to the position over the lathe most convenient for the operator to grasp its lower end with one hand. By moving the shipper to the left

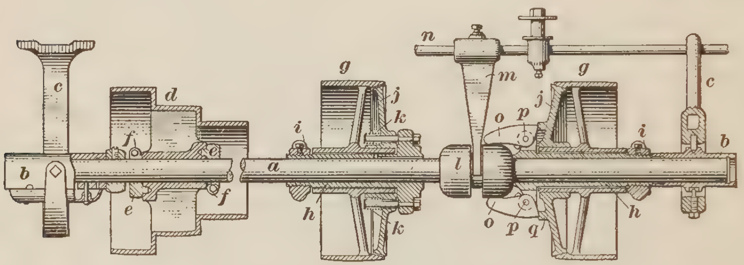


Fig. 3

the clutch in the pulley f_1 is set, and the lathe belt j will be driven in the direction shown in the arrow. By moving the shipper to the right the clutch in the pulley h_1 is set and the belt j will be driven in the opposite direction, thus reversing the lathe. When the shipper is held in its mid-position, both pulleys run free on the countershaft and the lathe is not operated.

6. Details of Double-Clutch Countershaft.—The details of a double-clutch drive operated by a shipper, as in Fig. 1, are shown in Fig. 3. The countershaft a is held in two boxes that are supported by the hooked lower parts of the hangers c. The cone pulley d is attached to the shaft by two split collars e having clamping bolts f. A projection on the side of each collar enters a hole drilled in the end of the hub and so locates and drives the cone. Some cone pulleys are held by setscrews.

7. The two clutch pulleys *g* run on bushings *h* secured to the shaft *a* and are kept in place by the collars *i*. The inner ends of the hubs of the loose pulleys *g* are turned and carry the cones *j*, which are beveled at their outer edges to fit corresponding bevels on the pulleys. When these cones are out of contact with the pulleys *g* and the latter turn freely on their sleeves, the lathe is idle. The cones are held away from the pulleys by the pressure of the coiled springs *k*. Between the pulleys, and free to slide along the shaft, is a spool *l* that may be moved by the arm *m* attached to the shifting rod *n*. The sleeve *h* on which each pulley turns carries at its inner end two fingers *o*. When the spool is moved to the position shown, it spreads these fingers, which are pivoted on pins *p*, and the short outer ends of the fingers are thus pressed against the ring *q* that is part of the cone *j*. This pressure forces the cone into the pulley *g* and the two turn as one piece. Thus the motion of the pulley is communicated through the cone to the sleeve and to the shaft *a*, and thence through the cone *d* to the lathe. The pulleys *g* turn in opposite directions, as shown by the arrows on pulleys f_1 and h_1 in Fig. 1, so that by moving the spool to the other pulley the direction of motion is reversed. The two pulleys and their cone clutches are alike.

8. Cone-Driven Headstock.—A lengthwise section of a headstock, as ordinarily used on a medium-sized engine lathe, is shown in Fig. 4. A rigid casting supports the hollow steel spindle *a*, the hole being tapered at its inner end to receive the live center *b*. The hole permits a rod to be passed through the spindle to drive out the center *b*, and also permits the machining of bars or rods passed through the spindle. The inner end of the spindle is threaded on the outside to receive the face plate *c*, chuck, or special holding fixture. It also has a collar *d*, which gives back support to the face plate and determines its accuracy of running.

9. The outer end of the spindle does not extend entirely through the left-hand bearing. To support the outward end thrust of the spindle a fiber ring *f* is placed against the end of the spindle and a plug *g* is screwed into the end of the bear-

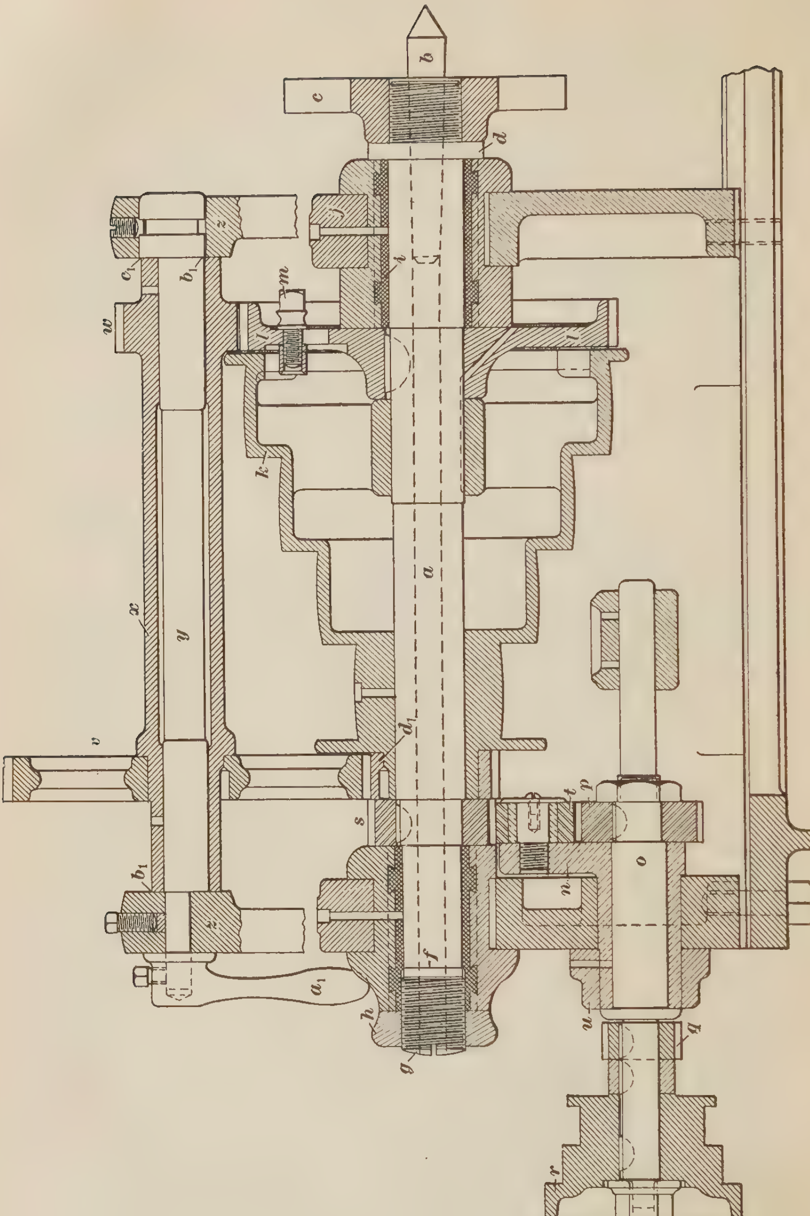


Fig. 4

ing and against the ring. A nut *h* locks the plug *g* after it has been correctly set. Each bearing consists of a cast-iron box lined with Babbitt metal *i*. These boxes are split horizontally into halves and fitted into square slots in the frame. The tops are held down by the caps *j*. Oil holes extend through the caps to the spindle.

10. Details of Cone-Pulley Drive.—The cone-pulley *k*, Fig. 4, is loose on the spindle. It can be connected to the spindle by fastening it to the gear *l* by means of the screw *m*. The gear is keyed on the spindle. The screw *m* may be moved in a slot near the rim of the gear *l* so as to lock the gear to the pulley and cause the spindle to revolve at the same rate as the cone pulley.

A brass bushing *n* that extends through the lower part of the headstock frame supports a shaft *o*. The gears *p*, on the inside of the bushing *n*, and *q* on the outside, are keyed to the shaft *o*, together with the cone pulley *r*. The gear *p* is driven by the spindle gear *s* by means of the gear *t*, or one just behind it, the pair of gears being arranged so as to operate the shaft *o* in either direction.

A handle on the hub *u*, Fig. 4, attached to the bushing *n*, is used to reverse the motion. This is used when it is desired to reverse the motion of the carriage, as the cone pulley *r* is connected by a belt to a similar pulley on the end of the feed-rod.

11. Details of Reversing Gears.—In some types of engine lathe the reversing gears *s*, *t*, and *p*, Fig. 4, are placed on the outside of the headstock casting, as shown in the headstock in Fig. 5, and in Fig. 6 (*a*) and (*b*), which is an end view of the same headstock. For the sake of clearness the same reference letters have been used in Figs. 4, 5, and 6. When the handle *u*, Fig. 6 (*a*), is up, motion is transmitted from the gear *s* through the gear *t* to the gear *p*, as indicated by the arrows. When the handle *u* is down, as in (*b*), the gear *t* is moved away from the gear *s*, and the gear t_1, that had been revolving idle, is brought against the gear *s*. Motion is then transmitted through the gears from *s* to t_1, from t_1 to *t*,

and from t to p, thus reversing the direction of motion of the gear p, as indicated by the arrows.

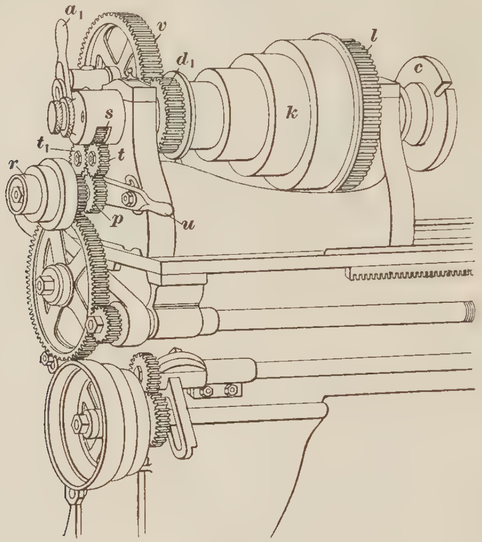


Fig. 5

In Fig. 6 (a) and (b) is also shown how the headstock is fitted to the **V**'s, a and a_1 of the lathe bed. The two outer **V**'s, b and b_1, are used by the saddle that carries the cutting tool.

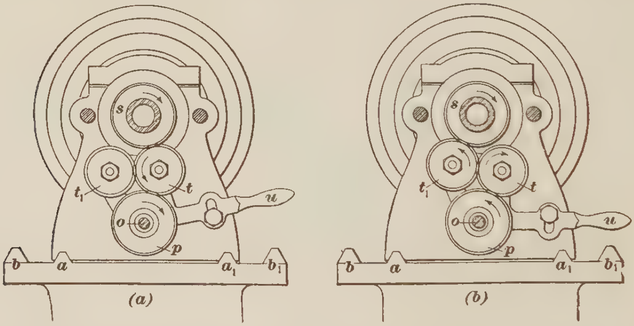


Fig. 6

12. Friction-Geared Headstock.—A friction-geared headstock is shown in Fig. 7. In (a) is shown the spindle a fitted with two pairs of bronze friction-shoes b and c; in (b) are

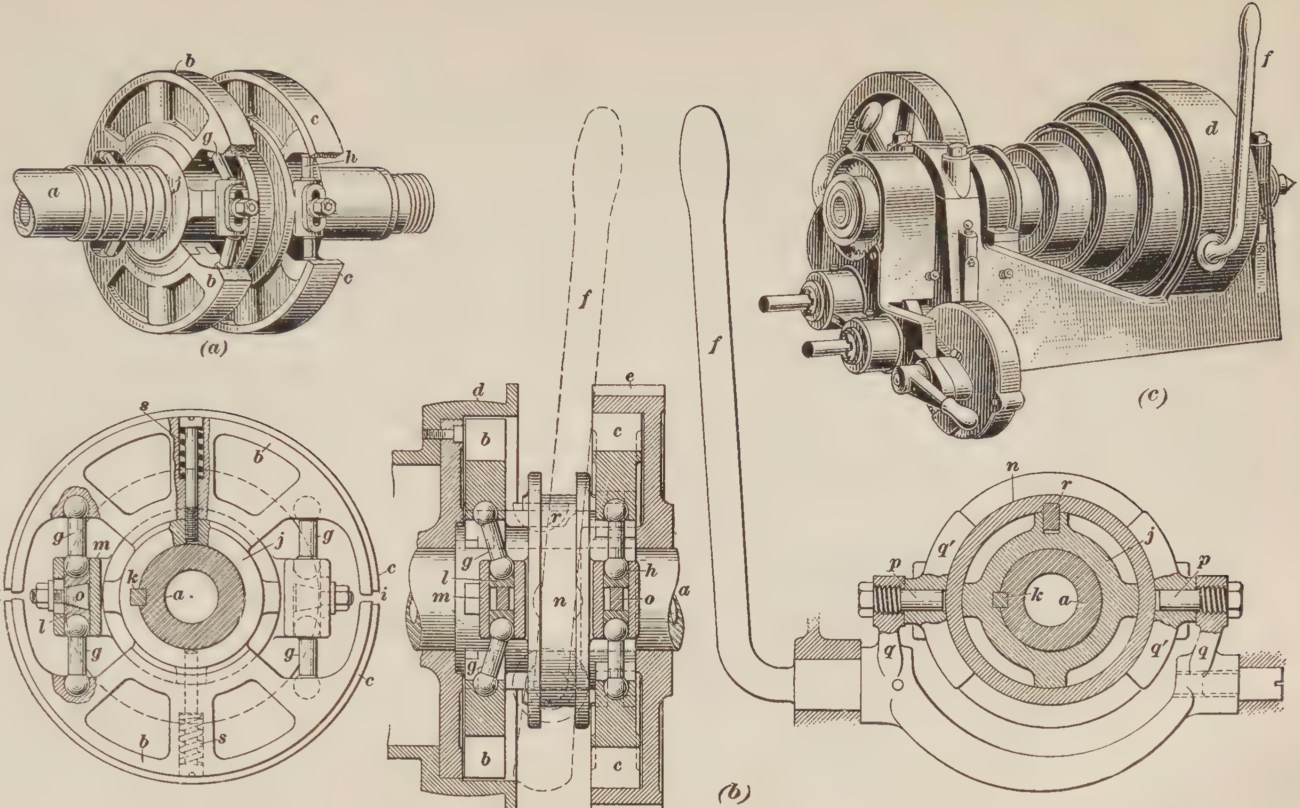


FIG. 7

shown the details of the shoes, and in (*c*) is given the assembled headstock with the gears and clutch shielded. The shoes *b* fit loosely in the largest step *d* of the cone, and the shoes *c* are in the spindle gear *e*. The cone is clutched to the spindle when the handle *f* is thrown to the left; both the cone and the spindle gear are loose when the handle is vertical, as shown in (*c*); and the gear is clutched to the spindle when the handle is shown to the right, as shown in (*b*).

There are two toggles made up of pins *g* and *h*, respectively, (*a*) and (*b*), in each clutch. The toggles separate the pairs of shoes at the joints *i* and press them against the friction surfaces of the cone and the gear. The hub *j* of the shoes, toggles, etc., is keyed to the spindle *a*, as shown at *k* in (*b*). The toggle in the cone clutch consists of two heavy spherical-ended pins *g*, with their outer ends fitting sockets in the shoes *b*, and their inner ends rest in socket blocks *l* in the jaws *m* on the sides of a grooved ring *n* located between the two friction units *b* and *c*. There is a wedge *o* between the socket blocks *l* for spacing the blocks and adjusting the tightness of the clutch grip.

Pins *p* project from the inner sides of the two lugs *q* that are operated by the handle *f*. These pins hold the two fingers *q'* that slide in the groove of the ring *n*, which in turn can be moved along a key *r* on the outside of the hub *j*. Thus, the handle *f* by sliding the ring *n* back and forth along the hub operates the toggles. A spring *s* in each shoe forces the shoes away from the cone and gear when the toggles are released, so that a quick stop is made.

13. Back Gears.—When the work must be turned at a slower speed than the step-cone *k*, Figs. 4 and 5, can provide, the back gearing is brought into action, and a heavier cut can be taken. The back gearing consists of a pair of gears *v* and *w* and a sleeve, or quill, *x*, that is loose on the shaft *y*. The bearings of the shaft *y* in the brackets *z* are eccentric with the center line of the shaft. Therefore, when the eccentric shaft is given a half turn by the handle a_1, the point b_1 rises to the location c_1, and the quill with the back gears *v*

and w is moved away from the spindle, throwing the gears out of mesh with the gears d_1 and l on the spindle a. Conversely, by turning the handle a_1 to the position shown in Fig. 4, the back gears are brought into mesh. In this case the gear l must be disconnected from the cone pulley k. The power from the cone pulley will then pass through the cone gear d_1 and the back gears v and w to the spindle gear ***l***.

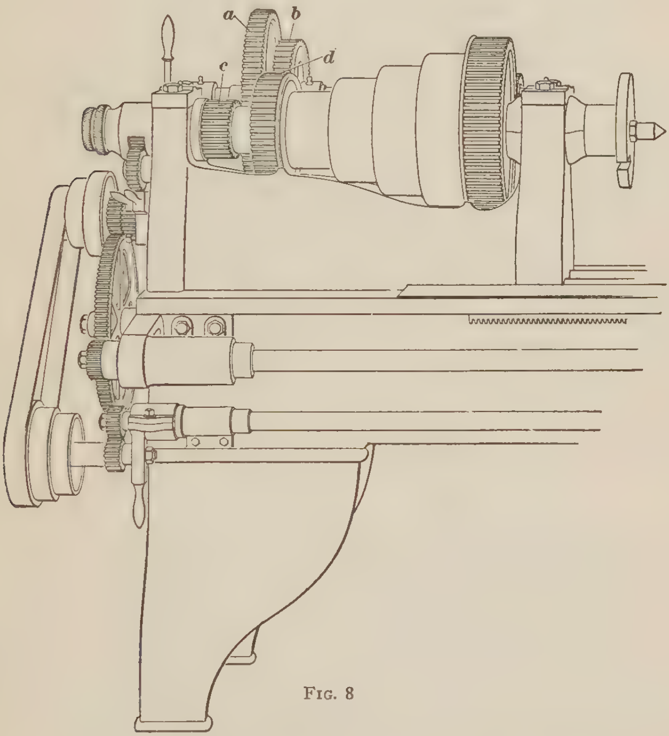


FIG. 8

14. Double Back Gears.—When two changes of speed are desired with the back gears, a second pair of gears of different sizes from the first pair is used. This combination, as in Fig. 8, on the lathe is called double back gears. The gears a and b are pinned together and are free to slide on a key in the back-gear shaft, but must turn with the shaft. When moved to the left position, the larger gear a meshes

with the smaller gear *c* attached to the cone, and there is the greatest reduction of speed. When the gears *a* and *b* are moved to the right-hand end of their seat, the gear *b* meshes with the gear *d* that is attached to the cone. The gears *b* and *d* are nearly of the same size, and therefore this combination gives a less change of speed than the first one. When the gears *b* and *d* are engaged, the back gear *a* is opposite the space between the cone gears *c* and *d*.

15. Tailstock.—A longitudinal section of one form of tailstock, used on small and medium-sized engine lathes, is shown in Fig. 9. The bottom part, or base, *a* is fitted to the **V**'s of the bed. The top of the base has a groove to receive projections under the body and aline it squarely across the lathe. The barrel *b* supports the dead center *c* and the mechanism for adjusting it. The tapered shank of the center fits into the end of a steel tail-spindle *d*, which may be moved horizontally by the long left-hand screw *e* in the nut *f* and operated by the handle *g*. When the tailstock spindle is drawn in until the nut *f* nearly touches the collar *h* on the screw *e*, the dead center is forced from its seat and can be easily removed.

16. The tailstock is moved into any position across the bed by the two screws *i*, one on each side of the base, and held there. Usually two zero lines *0–0* are used to indicate the exact central position of the tailstock body on its base. The tailstock is clamped to the bed by the use of a long bolt *j* having a nut *k* on top of the foot-piece *l* and a bar *m* under the **V**'s of the bed. This clamp bolt must be slacked off while the screws *i* are operated. By loosening one screw and tightening the other, any required sidewise adjustment is made. The foot-piece *l* is made low and the web *n* set back of the center line so as not to interfere with the tool support when swung around to operate on the end of the work. A hole *q* in the top of the frame makes a handy receptacle for the oil needed for the center hole in the work. To apply the oil the cover cap *r* with its attached wire is used as a swab or dropper.

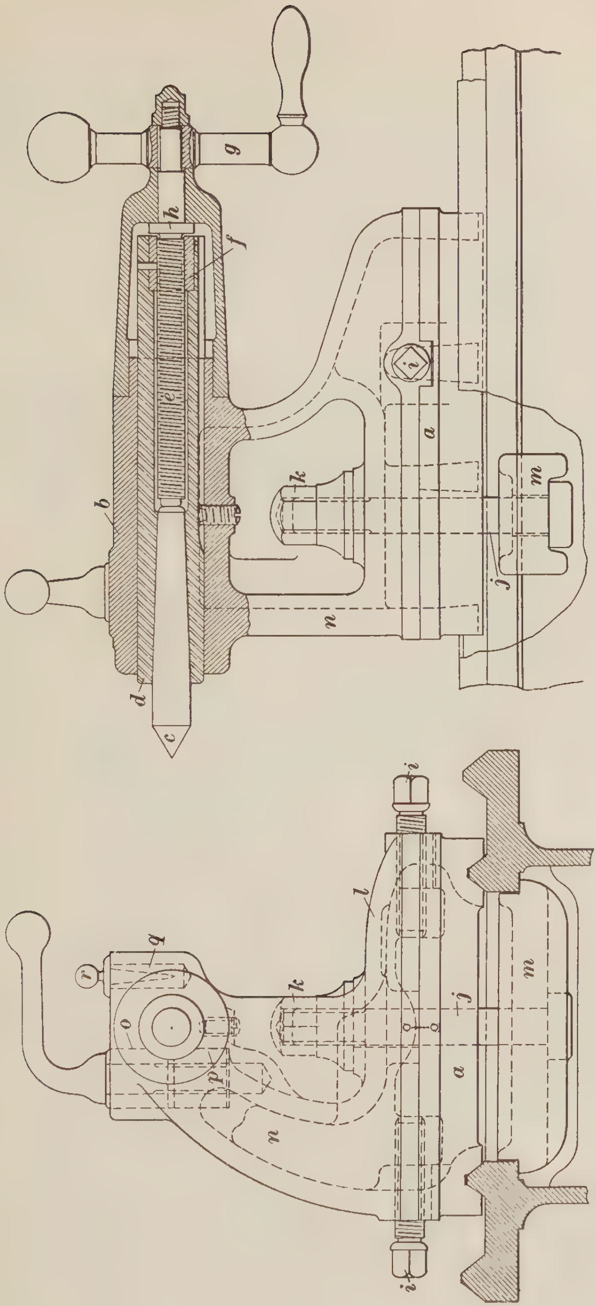


FIG. 9

17. Large Tailstock.—The details of a large tailstock are shown in Fig. 10. It consists of a base *a*, fitting the **V**'s of the lathe, with a cross-slide *b* on its top for the sidewise adjustment of the centers. The slide is prevented from moving endwise on the base by a tongue and groove *c*. The base is secured to the bed by clamp bolts *d* extending through the anchors *e*. The top carries the dead spindle *f* and the dead center *g*.

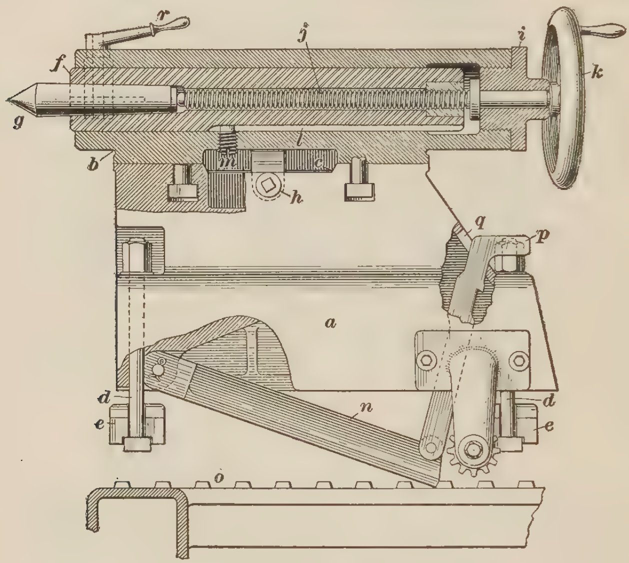


FIG. 10

The sidewise setting of the tailstock is made by an adjusting screw *h* on each side of the tailstock. These screws pass through holes in the lower part and enter tapped holes in corresponding lugs in the other part or the reverse. In the case of very large tailstocks the two cross-adjusting screws are both in front, one being tapped into the base and the other into the top part; this saves making trips around the end of the lathe to make adjustments. The back end of the spindle bore is tapped and closed by screwing in the butt *i*. Passing through the butt is the left-hand adjusting screw *j* operated by the hand wheel *k*. In the lower side of the spindle

is cut a keyway *l* in which fits a setscrew *m* that is flattened on two sides. This forms a key that prevents the spindle from turning, but allows it to move endwise.

18. Binding the Tailstock Spindle.—Binding, or clamping, of the tailstock spindle is invariably done at the front end of the spindle, that is, the end nearer the work, by merely splitting the end of the barrel a short distance and putting in a binder screw as at *f*, Fig. 10. The lever *r* turns the screw. This is not considered the very best construction, as it weakens the barrel and does not entirely surround the spindle with the mass of iron necessary to absorb vibrations. Therefore, the two-part bushing shown at *o* and *p*, Fig. 9, is sometimes used. The details of this bushing are shown in Fig. 11. The two parts *a* and *b* are set in a vertical hole in the lug *c* of the barrel *d*. The lower part *b* is threaded to receive the clamp screw *e*, operated by the lever *f*. Both parts have a curved section *g* that fits the spindle *h*. To bind the spindle, the parts *a* and *b* must be drawn together by the clamping action of the screw *e*.

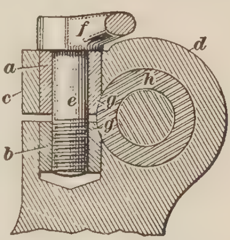


FIG. 11

19. Tailstock Thrust.—The tailstock is sometimes used to carry tools, such as drills, reamers, etc., to perform operations on the end of work held in a chuck. For such operations it is necessary that the tailstock be prevented from moving backwards due to the action of the work. Various arrangements are in use to accomplish this purpose. One arrangement, often used on large tailstocks, is shown in Fig. 10. A pawl *n* is secured to the under side of the tailstock, and the free end of it is allowed to fall into a rack *o* in the bed. The pawl is raised when not in use, and held out of the rack by the handle *p*, which hooks over the end of the slot *q* in the base. The handle *r* is a clamping lever used to lock the dead spindle in position after it has been properly adjusted. A light tailstock may easily be moved along the **V**'s of the bed

by hand; but the heavy tailstocks are usually provided with some form of moving mechanism, as explained later.

20. Lathe Carriage.—The lathe carriage *d*, Fig. 1, is composed of two parts, known as the *saddle* and the *apron*. The saddle, fitted to the top of the lathe bed, carries the cross-slide and the tool, and receives all the thrust exerted in cutting the work. The apron is secured to the saddle by screws. It hangs in front of the bed, and contains the gearing through which the feed-motion is transmitted from the feed-rod to the feed-rack. It also carries the split nut that engages the lead screw when cutting threads.

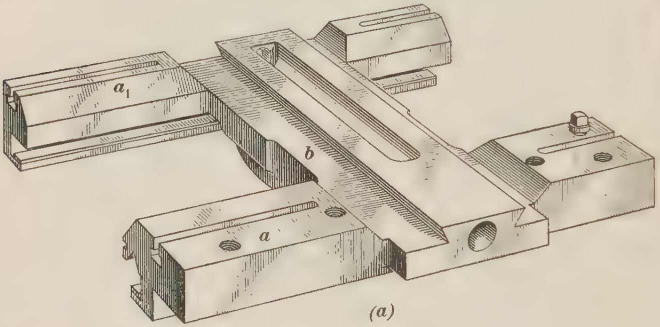


Fig. 12

21. Saddle.—One form of saddle is shown in Fig. 12 (*a*). It consists of an **H**-shaped casting with the two long parts *a* and a_1 fitting the lathe bed at the front and the back, and a cross-piece *b* uniting them at the middle. The cross-piece acts as a guide for the cross-slide that carries the cutting tool. As the saddle slides along the top of the bed, means must be provided for compensating for wear on the saddle. This is done by the use of strips of metal, known as *gibs*, that are placed between the saddle and the bed. These gibs may be adjusted by means of screws. The rear gib is usually a flat strip fitting the under side of the guide of the bed *c*, as shown in Fig. 12 (*b*), in which *d* is the flat gib and *e* the adjusting screw. The rear gib prevents the saddle from any upward motion. The front gib is usually a tapered strip, likewise adjustable by screws.

22. In Fig. 13 is shown a saddle with the cross-slide and tool-rest mounted on it. A hand screw operated by the handle *a* and attached to the part *b* moves the cross-slide *c*. On top of the cross-slide is a base *d* that may be swung around to any desired angle, as indicated by the scale *e*, and clamped by the nut *f*. A screw in *d*, operated by the handle *g*, moves the tool rest *h*. The type of tool rest having a swiveling base and a feed-screw for the tool rest is known as a *compound rest*.

23. Compound Rest.—The tool *i*, Fig. 13, is clamped under the plate *j* by the use of a central stud *k* and a screw *l*. To-

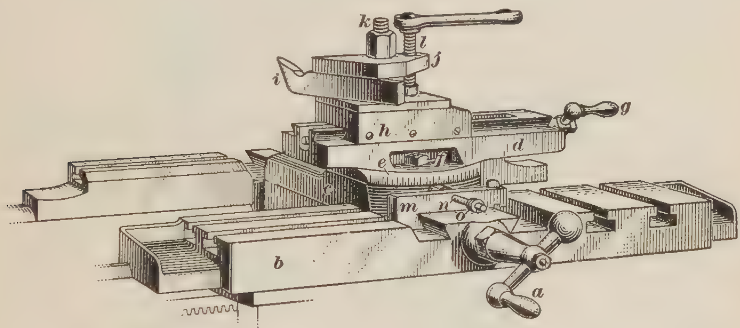


Fig. 13

clamp the tool, the plate is held horizontally when resting on the tool and the stud nut set against the plate. Then the outer edge of the plate is elevated by turning the screw *l*. This form of tool holder permits setting the tool in several positions around the central stud *k*. The motion of the cross-slide *c* may be gauged by means of the clamp *m*, the stud *n* attached to *c*, and the nut *o*.

24. Plain Rest.—Another type of saddle and tool rest, known as a *plain rest*, is shown in Fig. 14 (*a*), and is used principally on larger lathes. The height of the tool point is adjusted before clamping in the tool post, by means of wedges, washers, or rings, under the tool. These rest on the knurled ring *a*. The tool post screw *b* should not be screwed any

tighter than is necessary for the tool to do its work, as further tightening only injures the threads.

25. In Fig. 14 (*b*) is shown another style of tool adjustment. The tool rests on a chip, or rocker *a*, that is convex on its under side and fits the top of a concave ring *b* that rests on the tool block. The tool point *c* can be set at any height within given limits, as the rocker *a* under the tool may be adjusted to a position that will give a flat bearing for the tool.

26. Heavy-Duty Tool Rest.—A form of tool rest for heavy work is shown in Fig. 15 (*a*). The tool is clamped by the use of two straps *a* and four studs *b*. The straps are

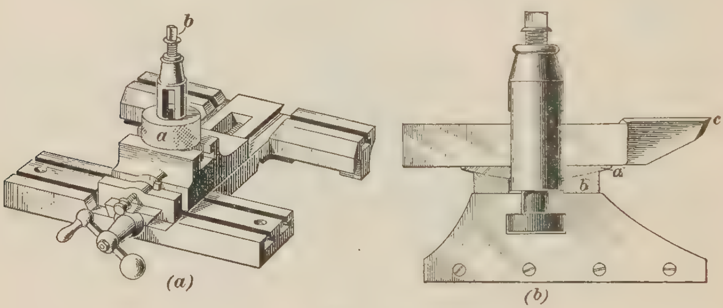


FIG. 14

held up by means of light springs to allow for the easy insertion of the tool and may be set at right angles to their present position. The body, or slide, *c*, of this tool rest is supported by a swivel plate *d* that may be swung about and clamped at any position on the graduated top of the cross-slide *e*. This arrangement permits the feed-screw *f* in the slide *c* to be set to feed the tool at any horizontal angle with the center line of the work. As there is no vertical adjustment of the tool, except by putting shims under the tool, it is necessary to shape and grind the tool carefully to obtain proper cutting. When the tool is correctly made, it is a simple matter to keep it ground at the same angles until redressing is necessary.

27. A compound tool rest for heavy work, that has a different form of tool clamp from the ones shown in Figs. 13

and 15 (*a*), is shown in Fig. 15 (*b*). The cross-slide *a* has swiveled on it a graduated plate *b* that can be set at any angle to the slide. A slide *c* on the top of the plate *b* carries the tool post, or tool clamp, *d*, and is moved by the feed-screw *e*. The tool post *d* may be moved along the slot *j* across the end of the slide *c* and clamped by the bolt *k*.

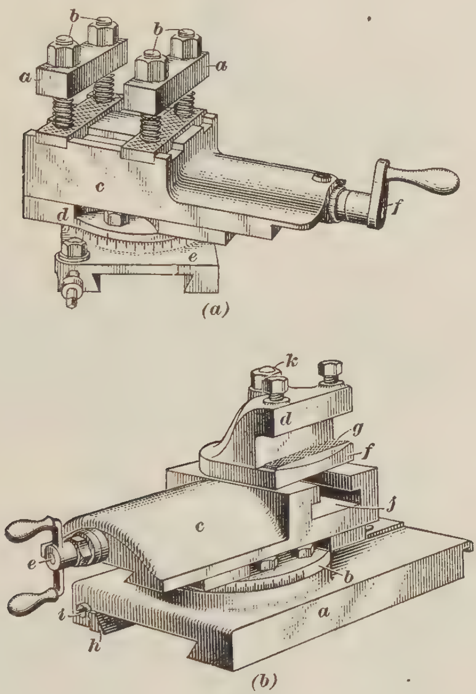


Fig. 15

On large lathes the compound rest is geared for power feed, and is used mainly for turning tapers that are beyond the range of the taper attachment of the lathe. The rest is set to the required angle by loosening the clamp bolts, and swinging the slide *c* and the plate *b* on the cross-slide *a*. The bottom jaw *f* of the tool clamp is made concave to receive a convex chip *g* that is checkered on its upper surface. The chip can be tilted in either direction to alter the height of the tool

point. The wear of the cross-slide may be taken up by means of the gib *h* adjusted by the screw *i*.

28. Rise-and-Fall Rest.—In Fig. 16 is shown a rise-and-fall rest. The upper part *a* supporting the tool holder is raised

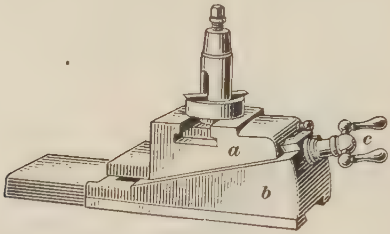


FIG. 16

or lowered along an inclined plane *b* by a screw which is also inclined and is operated by the handle *c*.

29. Aprons.—There are two types of lathe aprons. In one type the feed-mechanism is operated by the feed-rod, the lead screw is used for cutting threads, and the reversing gears

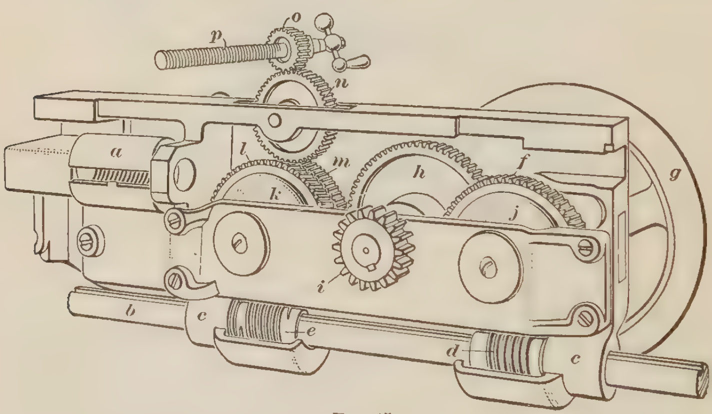


FIG. 17

are in the headstock. In the other, the lead screw alone operates the feed-mechanism and gives motion to the carriage when cutting threads, and the reversing mechanism is in the apron.

30. Lead Screw and Feed-Rod Operated Apron.—The type of apron shown in Fig. 17 is operated by both a lead screw and a feed-rod. The lead screw passes through the split nut *a*, which is closed on it when threads are to be cut. The lead screw is used to drive the carriage only for screw cutting. As previously mentioned, the lead screw *l*, as shown at *r*, Fig. 1, is rotated from the lathe spindle, through a set of gears, called *change gears*.

The feed-rod *b*, Fig. 17, is supported by the two bearings *c* at the bottom of the apron, and has a keyway, or *spline*, throughout its length. The two worms *d* and *e* are carried

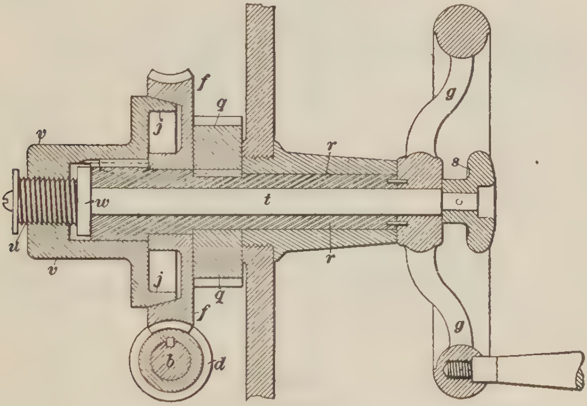


FIG. 18

by the bearings *c*, and slide along the feed-rod as the carriage moves; but they have short straight keys that engage the spline and always rotate with the feed-rod. The worm *d* drives the worm-gear *f*, which is loose on a sleeve to which the hand wheel *g* is pinned. The hand wheel *g* is used to move the carriage by hand.

31. Carriage Power Feed.—In Fig. 18 are shown the details of the carriage power feed. In front of the worm-gear *f* is a small gear *q* that is keyed to the sleeve *r*, and that drives the gear *h*, Fig. 17. The gear *h* turns the pinion *i* that meshes with the rack on the lathe bed. When the power feed of the carriage is required, a knob *s*, Fig. 18, attached to the

end of the clutch-pull shaft *t*, is turned and draws the cone *j* into tight contact with the worm-gear *f*. This is done by means of the threaded end *u* of the shaft *t* in the hub *v* of the cone *j*. The revolving worm-gear *f* then drives the cone *j*, the sleeve *r*, and the gear *q*, Fig. 18, and so drives the gear *h* and pinion *i*, Fig. 17, and moves the carriage along the lathe-bed rack. The hub *v* of the cone *j* is keyed on the end of the sleeve *r*, but can slide easily on the sleeve.

32. All the parts of the clutch, Fig. 18, including the sleeve *r* and the clutch-pull shaft *t*, should rotate together when the lathe is feeding, as otherwise there will be undue friction and wear. The shaft *t* is held from end-motion in the sleeve *r* by the collar *w* attached to shaft *t*, and by the knob *s*.

33. Power Cross-Feed.—When the power cross-feed is required, a cone clutch *k*, Fig. 17, similar to that shown in Fig. 18, is operated by a knob on the front of the apron. The worm-gear *l*, Fig. 17, is driven by the worm *e*. The clutch *k* holds the worm-gear *l* and the spur gear *m* together and drives the idler *n*. The purpose of the idler *n* is to drive a pinion *o* that is keyed on the screw *p* of the tool slide, thus moving the tool crosswise of the lathe.

34. Lead-Screw and Feed-Rod Carriage.—A sectional view of a carriage of the type shown in Fig. 17, together with its lathe bed, is shown in Fig. 19. The bed *a* is **U** shaped and cast in one piece with the pan *b*. The saddle *c* is guided on a wide **V** *d* along the front of the bed and rests on a flat track *e* at the rear.

The tool rest *f* is of the rise-and-fall type with the front end hinged and the height of the back adjusted by the hand screw *g*. The coil spring *h* keeps a tension on the rest, so that it will always be seated on the end of the screw *g*, and avoid any vibration of the carriage. The bar *i* of the taper attachment is set on a bracket *j*, attached to the bed. The cross-feed screw *k* is operated by the hand wheel or handle *l* and engages the cross-slide when the split nut *m* is closed. The small **V**'s *n* on the inner edges of the bed give alinement

to the headstock and tailstock. The feed-rack *o* is located as nearly as possible under the tool.

In the apron construction the feed-rod is shown at *p* and the lead screw at *q*. The clutch mechanism was described in connection with Figs. 17 and 18.

35. Lead-Screw Operated Apron.—Front and back views of an apron, operated by a lead screw for providing the

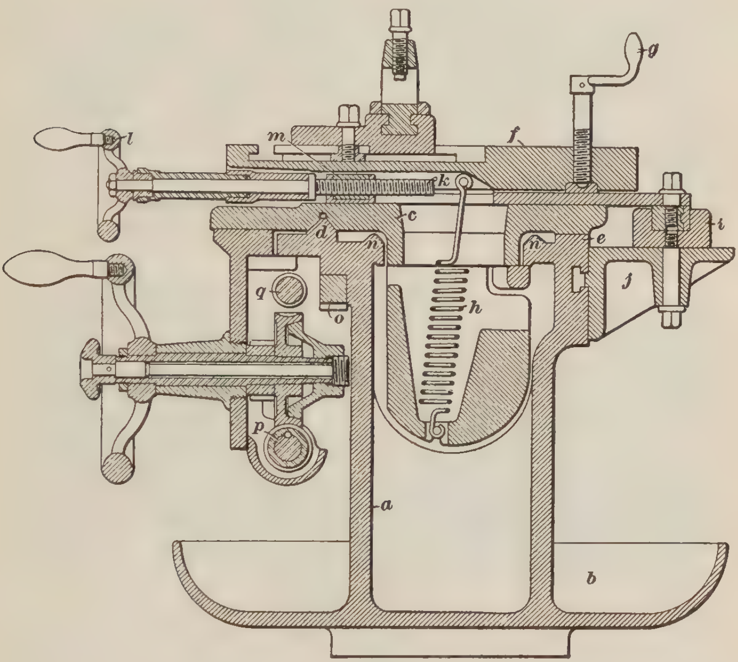


FIG. 19

feed and for cutting threads, are shown in Fig. 20 (*a*) and (*b*). The carriage is moved endwise by hand by turning the hand wheel *a*, which is fastened to a short shaft that passes through the front plate of the apron, and carries a pinion that meshes with the gear *b*. The gear *b* is fastened on the same shaft as the pinion *c*, and the latter meshes with a rack on the lathe bed; hence, when the hand wheel *a* is turned the pinion *c* is rotated and the carriage is moved along the bed.

In this case the lead screw performs all of the functions of the feed-rod, since it has a keyway, or spline, cut its full length in exactly the same way as the feed-rod, and drives the feed-mechanism through either bevel gears or worm-gears, just as the separate feed-rod does. In order that the sharp ends of the threads formed by the spline in the lead screw

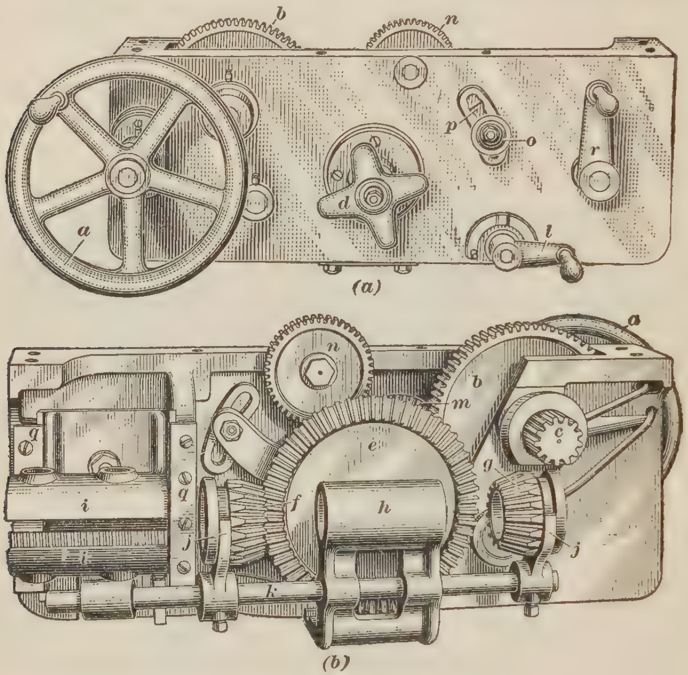


Fig. 20

shall not act as a tap and wear the split nut, the edges should be rounded off by filing.

36. The automatic feed of the apron shown in Fig. 20 is thrown in by turning the knob *d*, which tightens a clutch behind the bevel gear *e*. The lead screw passes through the bevel gears *f* and *g*, the sleeve *h*, and the split nut *i*. Each of the bevel gears *f* and *g* has a key that fits in the spline of the lead screw, so that it must turn with the screw, and yet may move endwise when the carriage moves. These bevel

gears have grooved collars in which fit the forks *j* fastened to the rod *k*. By turning the handle *l* at the front of the apron, the rod *k* is moved endwise and one of the bevel gears *f* and *g* is brought into mesh with the gear *e*. As the small bevel gears are on opposite sides of the large bevel gear *e*, and turn in the same direction, the gear *f* will rotate the gear *e* in one direction, and the gear *g* will turn it in the opposite direction. The automatic feed is thus reversed by moving the handle *l*, and when the handle is set vertical both gears *f* and *g* are out of mesh with the gear *e*, and there is no feed motion.

37. Behind the bevel gear *e*, Fig. 20, is a tumbler gear *m* that may be moved so as to mesh with either the cross-feed gear *n* or the gear *b* of the lengthwise feed. The tumbler gear is shifted by moving a knob *o* in the slot *p*. When it is at the top of the slot the automatic lengthwise feed is engaged, and when it is at the bottom the cross-feed is made automatic. The split nut is shown open at *i*. It consists of two parts that slide up and down in vertical guides *q*. When threads are to be cut and the carriage is to be moved by the lead screw and the nut, the handle *r* at the front is thrown over, thus moving the halves of the nut in their guides and drawing them together around the lead screw. The bevel pinions *f* and *g*, of course, are both out of mesh with the gear *e* when the split nut is closed on the lead screw.

38. Worm-Gear Operated Apron.—The worm-gear apron, Fig. 17, is more simple that the bevel-gear type, Fig. 20. Its feed-rod speed can be greater, as the worm gears give higher ratios. On the other hand, there is not the same opportunity to secure the feed reversal as in the bevel-gear type; nor can there be an automatic arrangement to prevent the split nut from being closed around the lead screw at the same time that the cross-feed is thrown in, nor can both the cross and longitudinal feeds be prevented from being thrown in at the same time.

39. Triple-Geared Headstock.—A slow speed lathe intended for heavy work is illustrated in Fig. 21. Its bed

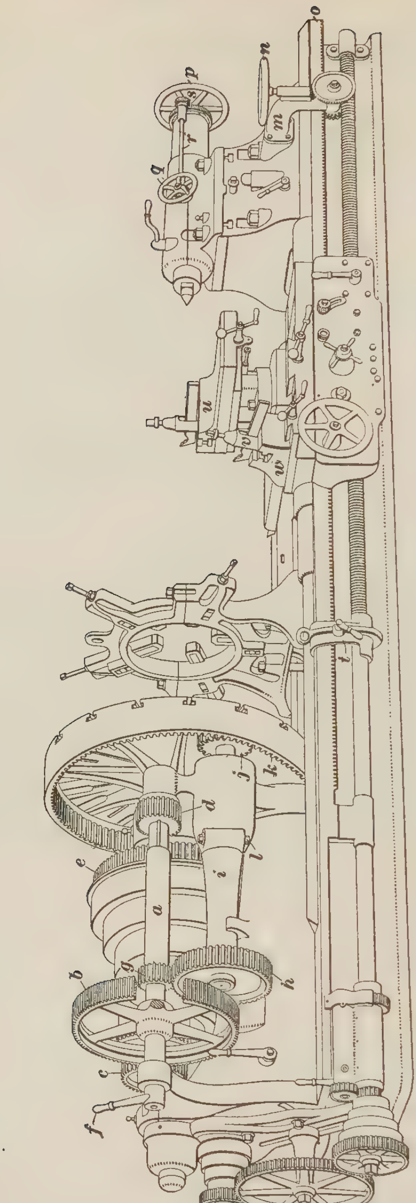


FIG. 21

rests directly on the foundation to gain extra rigidity. The speed-reducing gears are located on two shafts on the front of the headstock. The first reduction from the cone speed is by a shaft *a* with a gear *b* driven by the cone pinion *c*. The shaft *a* is supported in eccentric bearings so that its gear *b* and pinion *d* may be meshed or not with the cone pinion *c* and spindle gear *e*, respectively, by moving the handle *f*.

The next speed reduction is attained by the use of a pinion *g*, also on the shaft *a*, and a gear *h* on a shaft that is supported in the casing *i*. This second shaft drives the pinion *j* that meshes with the internal gear *k* in the back of the face plate. A guard is fastened over the pinion *j* to prevent the operator from getting his fingers caught between the pinion and the internal gear.

40. Operation of Triple-Geared Headstock.—To use the first set of gears, push the handle *f*, Fig. 21, to its farthest position. This will mesh the gear *b* with the cone pinion *c* and the pinion *d* with the spindle gear *e*, and the spindle and face plate will be driven the same as explained in connection with Fig. 4. It is also required in this case that the gear *h* be shifted from the pinion *g*. This is done by turning the short vertical stud *l* with a wrench, which moves the shaft with its gear *h* to the left and also disconnects the shaft from the hub of the pinion *j*.

41. To use the triple gearing the pinion *d* must be moved along the shaft *a* from the spindle gear *e* as shown. Then the gear *h* must be meshed with the pinion *g* on the shaft *a*. This is done by turning the stud *l*, which also connects the shaft of gear *h* to the pinion *j* that drives the face plate.

42. Moving Tailstock on Large Lathe.—On small engine lathes, as shown in Fig. 1, the tailstock is secured to the bed by a clamp bolt, and can be moved by loosening the bolt and sliding the tailstock over the **V**'s of the bed to the desired position by hand. The weight of the tailstock on large lathes makes this difficult, or impossible, and some special device is necessary to move it. The lathe shown in Fig. 21 has an

arm *m* attached to the tailstock and provided with a hand wheel *n* that operates the gearing arranged to engage with the rack *o*. By this device the tailstock can easily be moved by hand.

43. If no provision has been made for connecting the tailstock to the feed-rack, it may be connected to the carriage by a hook. Then by using the power feed the tailstock can be moved with the carriage to the position desired. Sometimes the tailstock is so long that it is not convenient to operate the spindle by the hand wheel *p*, Fig. 21, and the auxiliary hand wheel *q*, the shaft *r*, and the gearing at *s* are provided, thus enabling the operator to control the spindle while he is close to the carriage.

44. Lead-Screw Supports.—In the case of a small lathe, the lead screw and feed-rod are supported only at the ends and in the apron. With long lathes, an additional support, as shown at *t*, Fig. 21, becomes necessary. Sometimes several of these are used.

45. Tool Rest for Work of Large Diameter.—In most lathes the tool is secured in the ordinary tool post, as at *u*, Fig. 21. But it is sometimes necessary to turn work that cannot be swung over the carriage. In such a case, a tool post *v* is placed on an auxiliary slide *w* at the front end of the carriage. This tool post is located considerably lower than the lathe centers, and in order to apply the ordinary tools at the proper cutting angles, the top of the slide *w* on which the tool rests must be inclined at an angle that will line it up with the center of the work.

46. Motor-Driven Lathe.—An engine lathe having most of the details that have already been described, and designed for heavy work with high-speed steel tools, is shown in Fig. 22. It is driven by an electric motor *a* bolted on top of the headstock frame, which is made hollow to form a guard for the gearing. The lower half *b* contains oil to lubricate the gears. The motor is controlled by a controller box at the rear, which is operated by the hand wheel *c* through the shaft *d*,

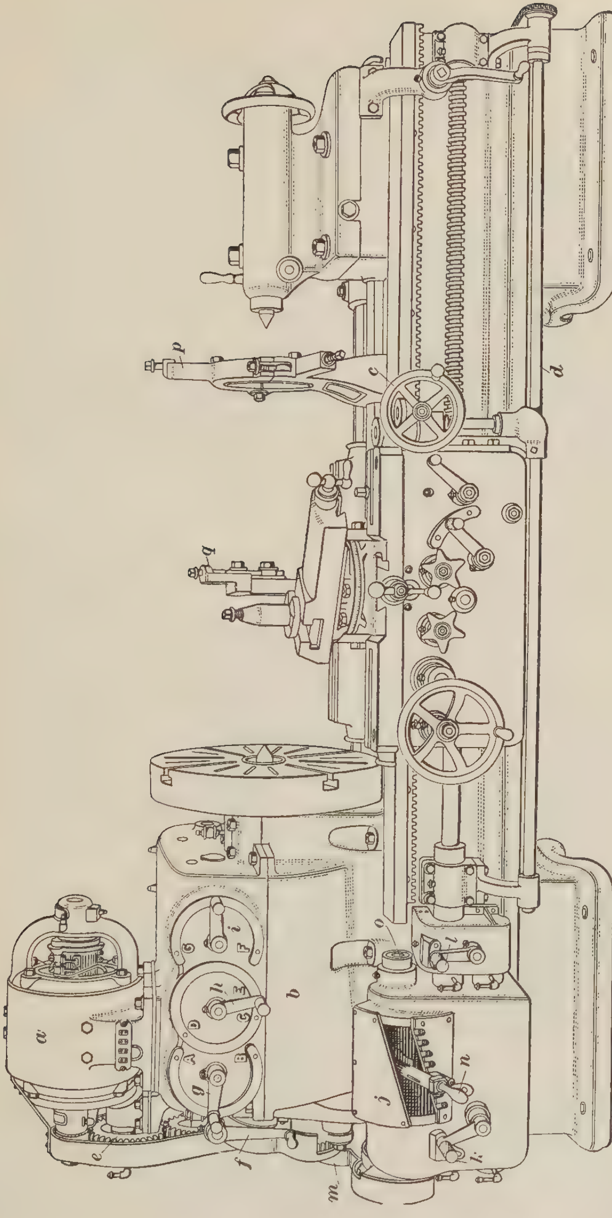


FIG. 22

and other connecting gearing. Power is transmitted to the initial driving shaft through the gear train *e* at the left end of the headstock. A powerful friction clutch operated by the lever *f* enables the driving shaft to be either connected to the gear train *e* or disconnected from it, thus starting or stopping the lathe. If the lathe is to be driven by a belt instead of by a motor, the lower gear of the gear train *e* is replaced by a plain pulley. The head contains gears that may be moved by the levers *g*, *h*, and *i*, thus altering the speed at which the work spindle is rotated.

Motor-driven engine lathes with large and heavy carriages are frequently supplied with a separate electric motor mounted directly on an extension of the carriage, and geared to the longitudinal feed-mechanism. By operating this motor the carriage may be run in either direction.

47. Geared Head.—A diagram of the gearing contained in the head of the high-duty lathe is shown in Fig. 23. This diagram shows the connections between the driving pulley and the work spindle. The initial driving shaft *a* is driven from the pulley *b* through the clutch *c*, and carries a pair of sliding gears *A* and *C* mounted on the same sleeve. These sliding gears are moved along the shaft *a* by the lever *g*, Fig. 22, and may be brought into mesh with the gears *B* and *D*, Fig. 23. The three gears *B*, *E*, and *D* are fixed to the sleeve *d*, which can rotate freely on the shaft *e*, but cannot move endwise. The gear *K* is keyed to the shaft *e*, and the pinion *L* is splined to it so that it can be slid endwise, but must turn with the shaft. The work spindle *f* has a sleeve *g* loose on it. On the sleeve *g* are splined the two sliding gears *G* and *H*, and the third gear *I* is keyed to the sleeve *g*. The clutch gear *F* is loose on the spindle *f* and the gear *M* is keyed to it. The clutch *h* is splined to the spindle *f* and may be thrown in so as to engage with the sleeve *g*, and thus cause the spindle to turn with the gears *G*, *H*, and *I*. The clutch *h* is moved at the same time as the pinion *L* by the lever *i*, Fig. 22. When the pinion *L*, Fig. 23, is in mesh with the gear *M*, the clutch *h* is free, and when the clutch *h* is engaged, the pinion *L* is free.

The central lever *h*, Fig. 22, controls the movements of the sliding gears *G* and *H*.

Runs	Speeds	Ratios	Levers
A B D H	260	1 : 1	*B–E–G*
A B E G	181	1.4086 : 1	*B–D–G*
A B F	133	1.984 : 1	*B–C–G*
C D H	93	2.795 : 1	*A–E–G*
C D E G	65	3.937 : 1	*A–D–G*
C D B F	47	5.546 : 1	*A–C–G*
A B D H I K L M	33	7.812 : 1	*B–E–F*
A B E G I K L M	23	11.005 : 1	*B–D–F*
A B F I K L M	17	15.504 : 1	*B–C–F*
C D H I K L M	12	21.836 : 1	*A–E–F*
C D E G I K L M	8.3	30.760 : 1	*A–D–F*
C D B F I K L M	6	43.330 : 1	*A–C–F*

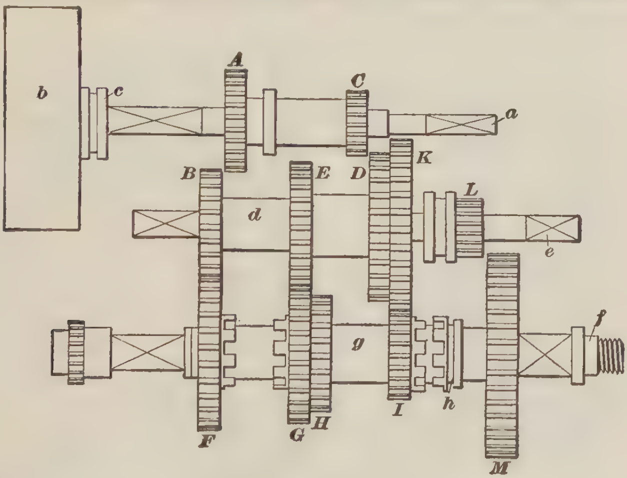


Fig. 23

48. The table given in connection with the diagram, Fig. 23, contains four columns. The first gives the runs, that is, the series of gears used to obtain a given speed. The second column gives the speed of the spindle in revolutions

per minute. The third column shows the ratio of speeds of the initial driving shaft and the spindle; that is, the number of turns made by the initial driving shaft to one of the spindle. The last column gives the holes to which the levers must be set, and these holes refer to the three sets shown at the front of the headstock in Fig. 22. For example, suppose that a spindle speed of about 50 revolutions per minute is required. The nearest value to this in the table, Fig. 23, is 47, which is obtained with the gears *C*, *D*, *B*, and *F* in mesh. The holes called for are *A*, *C*, and *G*. The lever *g*, Fig. 22, is therefore set to the hole *A*, which throws the slip gear *C*, Fig. 23, into mesh with the intermediate gear *D*. The lever *h*, Fig. 22, is set to the hole *C*, which throws the clutch on the gear *G*, Fig. 23, into mesh with that on the gear *F*. The lever *i*, Fig. 22, is set to the hole *G*, which throws the clutch *h*, Fig. 23, into mesh with that on the gear *I*. The motion is then transmitted from the gear *C* to the gear *D*, the sleeve *d*, the gear *B*, the gear *F*, the sleeve *g*, the gear *I*, the clutch *h*, and thence to the spindle *f*.

49. Quick-Change Gearing.—The rate of motion of the carriage for turning or for cutting screws may be varied by using the change-gear box *j*, Fig. 22, in connection with back gearing controlled by the levers *k* and *l*. A sectional diagram of the gearing in the change-gear box is shown in Fig. 24. The pinion *a* on the end of the tumbler shaft *b* is driven from the work spindle through a train of gears beneath the guard *m*, Fig. 22. This train is in all respects like that between the spindle and the lead screw of the lathe shown in Fig. 4. But whereas the speed of the lead screw in Fig. 4 is changed by using change gears of different sizes on the stud and the screw, the changes in the lathe in Fig. 22 are obtained by using the change-gear box and the back gearing. The lever *n* is connected to a sliding tumbler gear that may be moved endwise on the tumbler shaft *o*, and put in mesh with any one of eight gears forming a cone in the gear-box. In this way eight different speeds of the lead screw are obtained through the cone. But the back gears controlled

Runs	Ratios	Levers
Direct to screw	1 : 1	*B–C*
A B C D	1 : 2	*A–C*
E F G H	1 : 4	*B–D*
A B C D E F G H	1 : 8	*A–D*

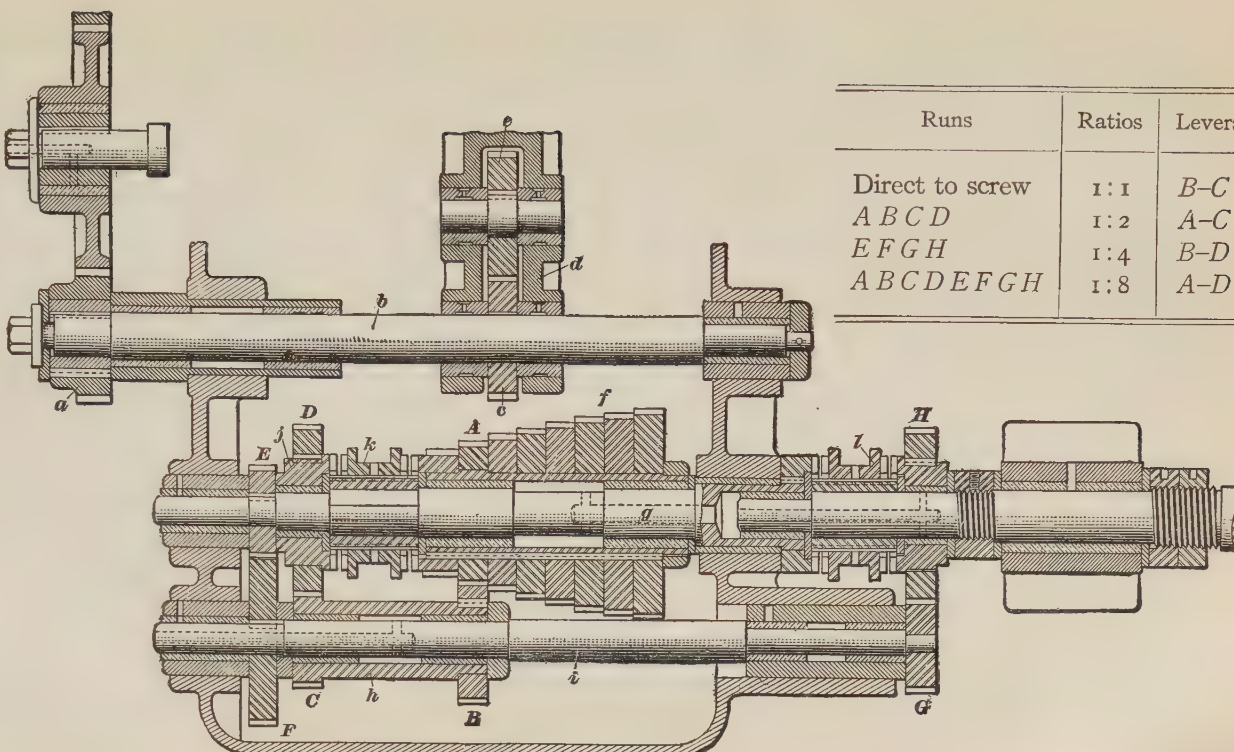


Fig. 24

by each of the levers *k* and *l* can be used to give two changes of speed in connection with each gear on the cone. There are thus 32 lead-screw speeds obtainable through the change-gear box and back gearing.

50. On the tumbler shaft *b*, Fig. 24, is a pinion *c* that can be slid along the shaft, but must turn with it. The pinion *c* is held in the forked end of a lever *d* that corresponds to the lever *n*, Fig. 22. The pinion *c*, Fig. 24, meshes with a pinion *e* that is also carried by the lever *d*, and that can be dropped into mesh with any one of the eight gears forming the cone *f*. These eight gears are keyed to a sleeve that is loose on the lead-screw shaft *g*. The back gears *B* and *C* are fixed on a sleeve *h* that is loose on the back-gear shaft *i*, and the back gears *F* and *G* are keyed to the shaft *i*. The gear *D* is fastened to a sleeve *j* that is loose on the shaft *g*, and the pinion *E* is fast to the shaft. The clutch *k* is splined to the shaft *g* and may be engaged with the cone *f* or the sleeve *j*. The gear *H* is keyed to a sleeve that is loose on the lead screw, and the clutch *l*, which is splined to the lead screw, may be engaged with the gear *H* or with the end of the shaft *g*.

51. Speed Ratios Through Back Gears.—The table given in Fig. 24 shows the speed ratios obtained through the back gears *A, B, C, D, E, F, G*, and *H*, and gives the runs and the holes to which the levers *k* and *l*, Fig. 22, must be set. The eight changes that furnish the coarsest feeds are obtained directly through the cone gears, without using the back gears at all. In these cases, the levers *k* and *l*, Fig. 22, are set to the holes *B* and *C*, respectively. The driving is then done from the shaft *b*, Fig. 24, through the gears *c* and *e* to one of the cone gears, through the clutch *k* to the shaft *g*, and through the clutch *l* to the lead screw. The eight gears in the cone thus give eight different speed changes when the drive is direct; that is, when no back gears are used. With the run shown in the second line of the table, the levers are set to *A* and *C*. This causes the clutch *k* to engage the sleeve *j*,

and the clutch l to engage the end of the shaft g. Thus, after driving through the cone, power is transmitted through the back gears A, B, C, and D to the sleeve j, then to the clutch k, thence through the shaft g and the clutch l to the lead screw. The use of these four back gears makes the lead-screw speed half as great as when the drive is direct; but as the drive may be through any of the cone gears, there are eight speeds possible with the back gears A, B, C, and D, depending on which of the cone gears is used. The two remaining runs in the table decrease the speed to one-fourth and one-eighth that obtained by direct driving.

52. Size of Lathe.—In the United States, the size of a lathe is designated by the diameter of the largest piece of work it is able to turn. This is called its *swing* and is usually stated in inches. Thus, a lathe intended to turn a pulley 24 inches in diameter, but no larger, is rated as a 24-inch lathe. In addition to the swing, the length of the bed is also taken into account in the size of the machine. This length is generally expressed in feet. The actual length of the work that can be swung on the centers on the most commonly used sizes of lathes, is about half the length of the bed. In Europe the swing of a lathe is the *radius* of the largest piece that can be turned; this means the distance from the lathe center to the **V**'s. Thus, a 24-inch lathe in America is termed a 12-inch lathe in Europe.

COMMON ATTACHMENTS

53. Forms of Lathe Centers.—Several forms of lathe centers are shown in Fig. 25. The form most used is shown in (a). The point usually has an angle a of 60°, but for very heavy work an angle of 75° or 90° is sometimes used, as it gives a stronger center. The body of the center is tapered to fit the hole in the spindle or in the bushing inserted in it. The standard Morse taper of $\frac{5}{8}$ inch per foot is generally used, as this is the same taper used on twist drills and most other taper shank tools. The Reed and Jarno tapers

of $\frac{6}{10}$ inch per foot are also used on lathe centers. The back end b of the center is turned smaller than the hole in

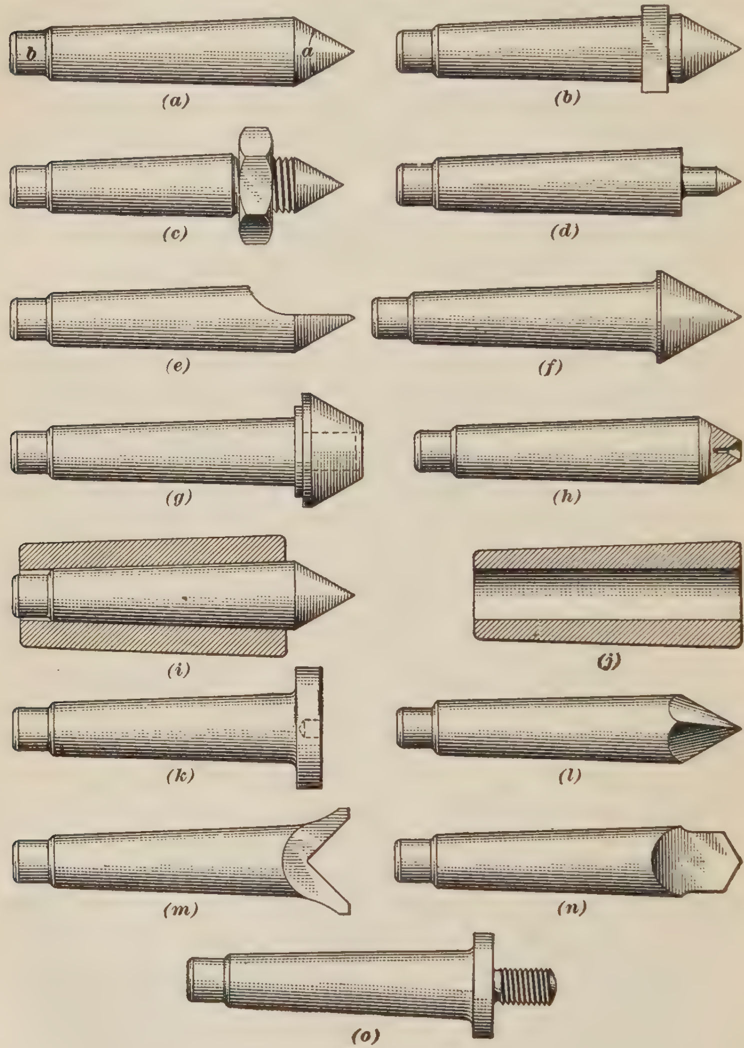


FIG. 25

the spindle, so that in case the end becomes battered and enlarged by the hammer action of the rod that is used to

drive out the center, it will not bind in the hole or damage the hole.

54. The center is driven out of the headstock, or live, spindle by passing a rod through the spindle, and it is backed out of the tailstock, or dead, spindle by running the spindle back until the inner or shank end of the center strikes the end of the spindle screw. The center (*b*) is used in a solid spindle, and to remove the center from the spindle a wrench is applied to the square formed on the center. The center (*c*) is drawn out of the spindle by the nut shown, which is screwed against the end of the spindle. This nut usually has 14 or 16 threads per inch. A projecting part of smaller diameter is formed on the center (*d*), which is used when an arbor does not extend through a hole in a piece of work. The half center (*e*) has nearly half of its diameter cut away, leaving a flat surface. It is placed in the dead spindle with the flat surface toward the tool, and the cut-away part allows the side tool to be run to the full depth of its cut without interfering with the center.

55. If the work has a hole through it, as in the case of a tube, or if the center hole in the work is unusually large, the centers (*f*) and (*g*) with a greatly enlarged end are used. The tip in (*g*) turns with the work, and sometimes a ball bearing is used in the tip. The center (*h*) has a center-hole in it and is used to support work that has pointed ends, and for work that is too small to have center holes drilled in it. A very large lathe spindle is often provided with a tapered bushing (*i*) that fits the taper of the spindle and allows a smaller center to be used in it. It is made of soft steel, which makes it cheaper than a large center wholly of tool steel. A smaller bushing, shown in (*j*), is made with a straight hole and, when placed in the tapered hole in the live spindle, serves as a guide for a boring bar held in the tailstock. The pad center (*k*), which consists of a good-sized flat disk, is used in the tailstock spindle when thin or flat pieces are to be drilled. The work is held by hand or by

a clamp against the pad and the tailstock is moved toward the drill held in the headstock spindle.

56. The square center (*l*) is sometimes used to ream center holes in the ends of short work. It has four faces, with the opposite corners making an angle of 60° with each other. It is put in the tailstock spindle and brought against the end of the work while the other end of the work is on the live center and forced to revolve with it. The forked center (*m*) is used in the dead spindle to support and guide round work while it is being drilled by a drill held in the live spindle. The starting drill (*n*) is a center flattened on

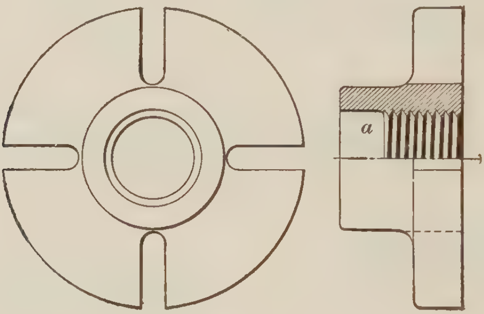


Fig. 26

two sides and formed into a flat drill. It is used in the dead spindle to start holes true where they are to be drilled by a less rigid tool, such as a long twist or flat drill. The center (*o*) is a work holder, usually threaded, and used in the live spindle for holding a nut or other internally threaded work while it is being operated on by the lathe tool.

57. Forms of Face Plates.—A lathe is provided with two face plates for general work. The plates are bored and threaded to fit the thread on the nose of the spindle, and the back end is generally counterbored to fit the plain cylindrical part of the spindle at the inner end of the thread, as shown at *a*, Fig. 26. The smaller of the two face plates is used to drive work that is held between centers. It has one or more radial slots cut in the flange to receive the tail of the

dog that drives the work that is supported on the lathe centers. When the face plate is used to drive work that is being threaded, it is more convenient to use one having but one of the radial slots extending clear to the edge. Then the work can be taken from the lathe for testing and can be reset without making a mistake in getting the dog in the wrong slot. The larger face plate is usually made with **T** slots extending from the hub to the edge, and with short slots extending through the plate between the **T** slots. It is used mainly for holding work to be machined accurately, but is also used as a driver when the smaller plate cannot be employed. Two

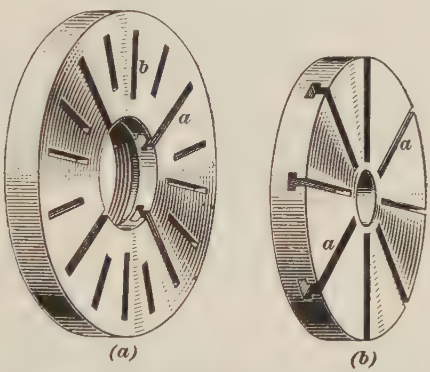


FIG. 27

forms of the larger face plate are shown in Fig. 27 (*a*) and (*b*). In (*a*) the **T** slots extend to the central hole and the bolt slots *b* pass clear through the plate. In (*b*) the **T** slots *a* extend to the circumference and there are no bolt slots.

58. Adjustable Jaws for Face Plates.—For securing work on the face plate, and to enable the operator to chuck similar pieces successively with the least amount of labor, adjustable jaws are made as shown in Fig. 28. The adjustable jaw usually consists of a block *a* in which the jaw *b* works. The blocks are clamped to the face plate by means of **T** bolts *c*. This really makes the face plate a special form of chuck. The jaws have the advantage that they can be placed evenly,

or they can be arranged unevenly to accommodate irregular work, some of the jaws either being placed nearer the center

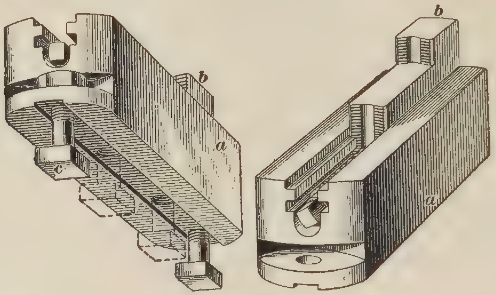


Fig. 28

than others, or being spaced irregularly in the different slots in the face plate. The entire piece that is attached to the face plate is usually called a *jaw;* but in reality only the portion *b* is the jaw, and these pieces *b* may be reversed, thus giving a greater range of work that can be held by this device.

59. Sometimes a simple form of jaw may be used, as shown in Fig. 29. This consists of an L-shaped casting *s*

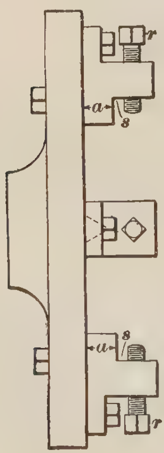


Fig. 29

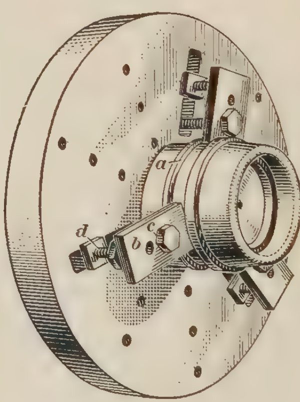


Fig. 30

bolted to the face plate and provided with setscrews *r* for securing the work. The shoulder below the point of the setscrew

should be turned off so that the dimension *a* is the same on all of them. This will enable the operator to place work against these shoulders during chucking.

60. Face Plate With Adjustable Clamps.—In some cases where the work has a shoulder, as shown at *a*, Fig. 30, simple plate clamps *b* are used. These clamps are fitted over the shoulder and adjusted to the correct height by the tension bolts *c*, that are movable in the slots of the face plate. The

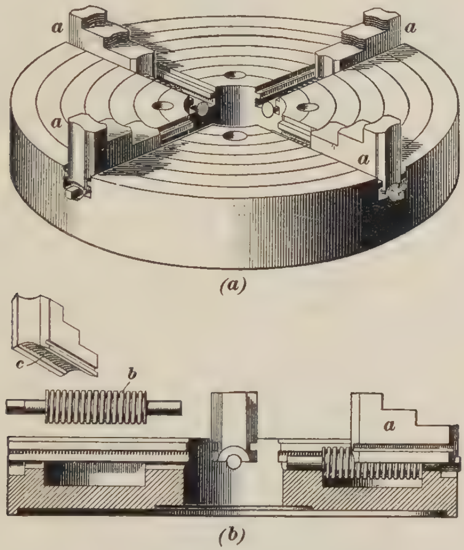


Fig. 31

clamps are then tightened on the work by either the bolts *c* or the pillar bolts *d*.

61. Action of Lathe Chuck.—When parts that are turned in the lathe are so shaped that they cannot be held between the lathe centers, it is often necessary to hold them in a chuck, such as is shown in Fig. 31 (*a*). The chuck is a steel or cast-iron disk that has radial slots in its face, in which slide a number of jaws *a*. The work is gripped by the jaws, which can be moved in or out by screws to accommodate various sizes of work. These screws shown at *b*, Fig. 31 (*b*),

engage teeth cut in the back of the jaws, as shown at *c*. The chuck itself is screwed on the nose of the headstock spindle.

62. Classification of Lathe Chucks.—Lathe chucks are classed as *independent, universal,* and *combination chucks*. Independent chucks are so arranged that each jaw is moved with an adjusting screw independent of the other jaws. Universal chucks are so constructed that when one jaw moves, the others move in the same direction a corresponding distance. Combination chucks are so made that they may be used either as independent or as universal chucks. Chucks are made with two, three or four jaws.

63. Independent Chuck. — An independent chuck is shown in Fig. 31 (*a*), and a sectional view of the same chuck with the jaws *a* reversed, in (*b*). Any irregular shape of work can be accommodated by the setting of the jaws of the independent chuck. It also has the advantage that, owing to the separate adjustment of each jaw, a turned piece can be so set in it that the surface will run true. If the independent chuck is used on work of regular shape, the time required to set the work can be reduced by marking two adjacent jaws of a four-jaw chuck after the first piece has been set true. When the piece is finished, it can be removed by loosening the marked jaws, the succeeding piece can be placed in position, and the marked jaws tightened. This will usually bring the work about true. It should be tested, however, and any necessary corrections made. This operation may be repeated for any number of pieces that are alike and work may be set central almost as quickly as in the universal chuck. Chucks used for general work on the lathe are usually of the independent type if they are 12 inches or more in diameter.

Chucks of this type are made as large as 3 feet in diameter. Work that would require the use of a very large chuck may be better operated on by fastening or bolting it to the face plate of the lathe. Circles, as shown, are scribed on the face of the chuck and used to set the jaws true.

64. Universal Chuck.—Chucks used on small lathes for holding round work are usually 6- or 8-inch universal chucks

such as is shown in Fig. 32. They grip the work quickly, as all jaws move at the same time, and they center it near enough in most cases. Large universal chucks are sometimes used, but they wear uneven with use, so that they

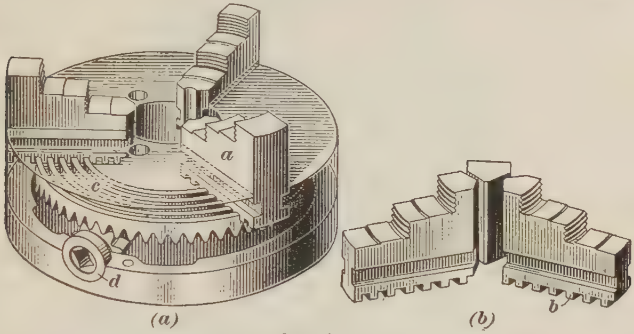


Fig. 32

will not center the work as true as can be done with the independent chuck.

The illustration at (*a*), Fig. 32, shows the jaws *a* located to grip the work on the outside, and the view in (*b*) shows the position of the jaws when it is desired to grip hollow

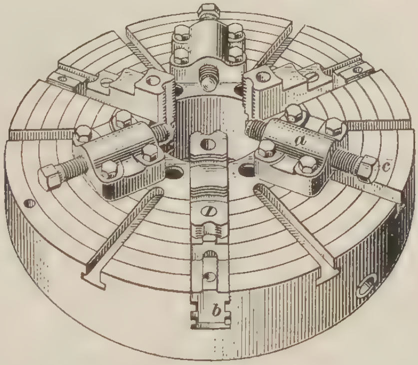


Fig. 33

work on the inside. The jaws of the chuck have square teeth *b* on their bottoms, and these engage a scroll *c*, or square spiral thread, cut on a disk at the back of the jaws. The back side of the disk has a bevel gear cut on it which is operated by

pinions, the outer end of one being shown at *d*. When any one pinion is turned by a square key or wrench, that fits in its end, the bevel gear is rotated, thus rotating the scroll *c* and causing all jaws to move an equal distance toward, or away from, the center of the chuck.

For heavy turning operations, universal chucks are sometimes provided with auxiliary jaws as shown at *a*, Fig. 33. They are placed between the regular jaws *b* and bolted onto the chuck. The work is chucked in the regular way by the standard jaws and then further clamped by tightening the screws *c* in the auxiliary jaws.

65. Combination Chuck.—A combination chuck, with the back cover-plate removed, is shown in Fig. 34 (*a*). In order to show its operation the illustration is drawn with a portion of the body ring left off. A pinion *a* is cut on each adjusting screw *f*, and these pinions engage with a circular rack *b* in the back of the chuck. When any one of the four adjusting screws is turned, the rack is rotated and the other screws are turned an equal amount. Thus all jaws are moved the same distance. To make this chuck independent, the rack must be lifted out of mesh with the pinions on the screws. The ring *c* rests against the back of the rack *b*, and cams *d* project from the back of the ring. When the ring is partially rotated by means of the knob *e*, the cams *d* drop into pockets, thus allowing the ring and the rack to move away from the pinions sufficiently to disengage. When this is done, each screw is independent of the others. When the ring is partly rotated in the opposite direction, the cams lift the ring and rack so that the latter again engages the pinions, and the chuck is again universal.

Another form of combination chuck is shown in Fig. 34 (*b*). Its combination feature consists of a rack *a* operated by a pinion *b*. On the back of the rack is a scroll *c* that meshes with a rack *d* on the back of the jaws. The independent feature has a two-part jaw slide with an adjusting screw *e* between the parts. A narrow **V**-groove *f* is cut in the screw, and a wedge-pointed index pin *g* is held against the screw

by a spring h. The click of the point when it drops into the groove indicates each complete turn of the screw, which moves the jaw $\frac{1}{8}$ inch.

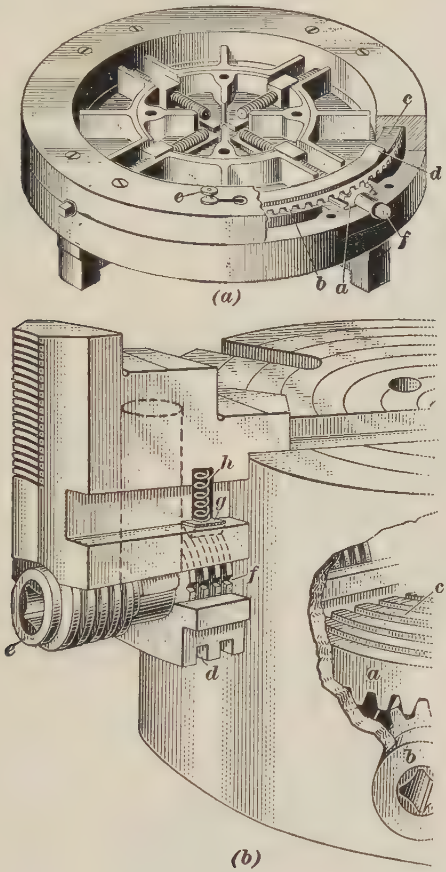


FIG. 34

66. After a combination chuck is used as an independent chuck for irregular work, the jaws will be out of true. To set the jaws true, each must be adjusted to a circle that is drawn on the face of the chuck, and then the rack must be thrown into gear. Combination chucks can be used to good advantage for some classes of irregular work. The chuck

is made independent, and after the work is once set true the combination can be thrown in. When the work is removed the jaws will all open together. If the next piece of work is set in the chuck in the same position relative to the jaws as the first, the jaws can be tightened and the work will run as true as the previous piece.

67. Drill Chuck.—Drill chucks of all kinds are placed on taper shanks fitting the holes in lathe spindles, or have taper holes for separate shanks or arbors, as illustrated in Fig. 35. They are used to hold straight-shank drills or small round work. The heavier drill chucks are sometimes employed

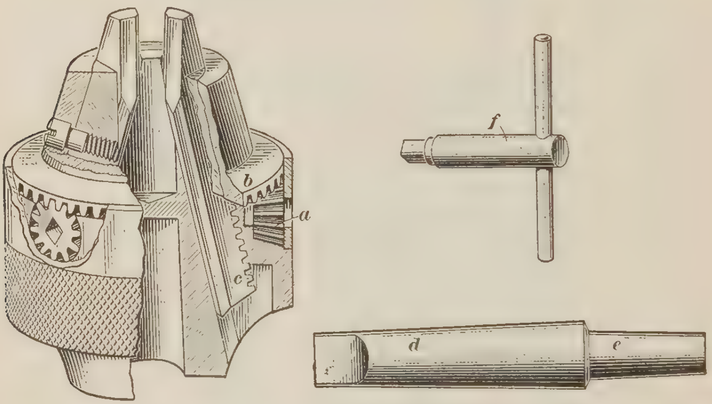


Fig. 35

for light turning, but as this is liable to spring them, they should not be used for this purpose. The chuck in the illustration is operated by the bevel pinion *a* which revolves the gear *b*, and this in turn moves the rack *c* on each jaw. The taper *d* of the arbor fits the spindle hole of the headstock, and the taper *e* fits the chuck. The smaller sizes of drill chucks are usually tightened by hand, and the larger sizes by a key *f*.

68. Hand-Lever Chuck.—The chuck shown in Fig. 36 (*a*) is operated by a hand lever which is part of the chuck itself. The purpose of this design is to save time both in clamping and releasing the work. The grip of the jaws can

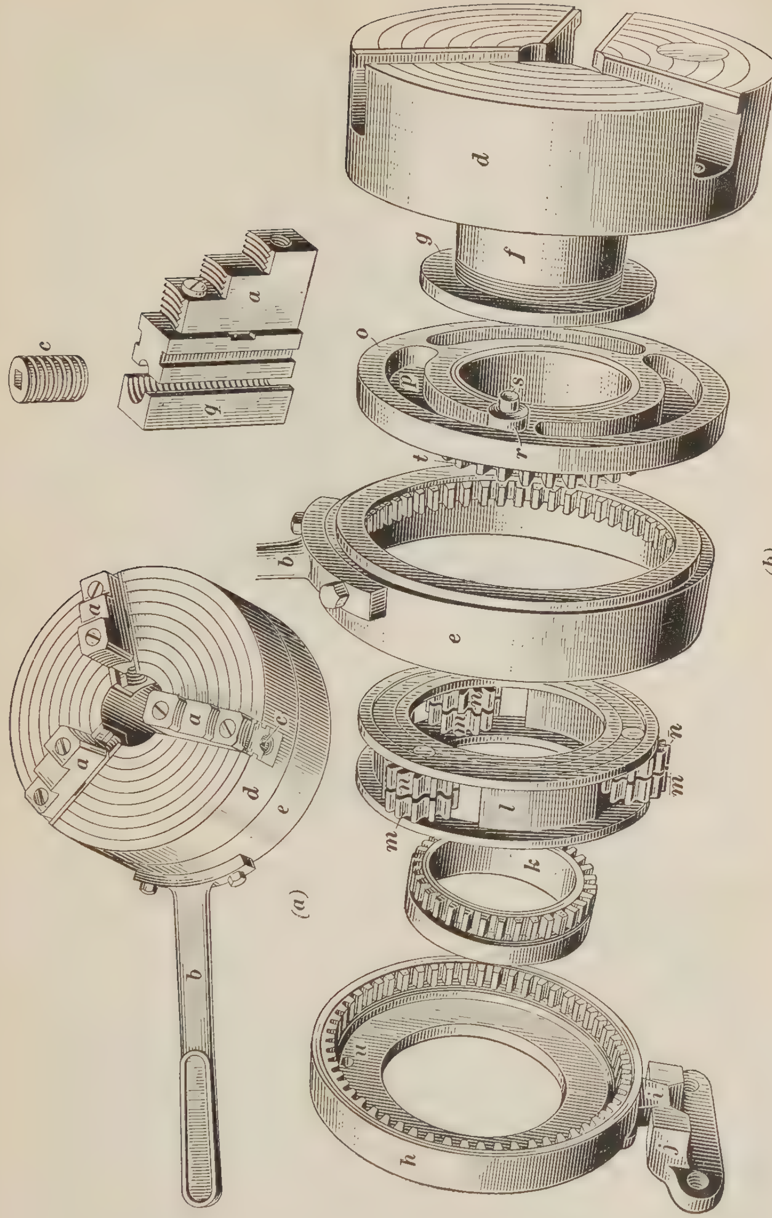


FIG. 36

be either tightened or loosened instantly while the lathe is in motion, and the work can be put in or taken out of the chuck without stopping the lathe. The jaws are universal in action and also have an independent adjustment to suit the diameters and forms of different work.

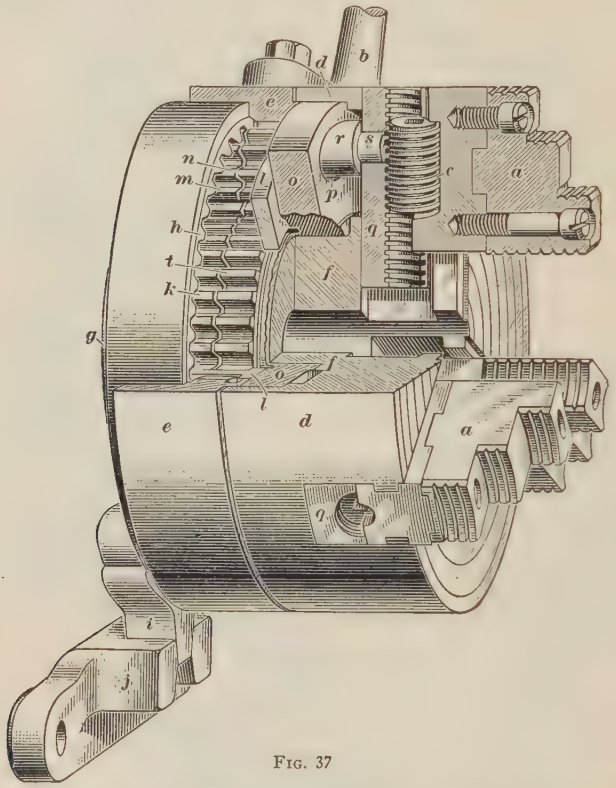


FIG. 37

The jaws *a* are operated by the lever *b*, and a socket screw *c* in each jaw permits of a separate adjustment. The chuck has two main parts—a body *d* that has a hub which screws on to the lathe spindle, and an internal gear *e* that is stationary except when revolved a short distance back and forth by the lever *b*.

69. Details of Hand-Lever Chuck.—The details of the hand-lever chuck are shown separated from each other in

Fig. 36 (*b*), and Fig. 37 shows a partial section of the parts when assembled on the hub *f* of the body *d*. The ring *g* screwed on the end of the hub *f* holds the parts together. The internal gear *h* together with the ring *g* encloses the back of the chuck, and the gear *h* is held stationary by means of a lug *i* extending into a forked bracket *j* attached to the headstock of the lathe. A small gear *k* is keyed to the hub *f*, and the outside of its hub has a running fit in the hole through the gear *h*.

A double ring, or spider, *l* carries three pairs of equal pinions *m* and *n*. A plate *o* with an inclined groove, or cam, *p* cut into its face for each jaw, is located in the body *d* just back of the slides *q* that support the jaws *a*.

There is a roller *r* in each cam-groove *p*, and each roller has a pin *s* that engages a hole in the back of a slide *q*. By this arrangement the jaws are made to slide a short distance in or out along the grooves across the face of the chuck when the cam-plate *o* is revolved back and forth.

70. Operation of Hand-Lever Chuck.—A gear *t*, Fig. 36, the same size as a gear *k*, is cut on the hub of the cam-plate *o*. The equal gears *k* and *t* mesh with the pinions *m* and *n* on the inside, and the equal internal gears *h* and *e* mesh with them on the outside, *h* with *m*, and *e* with *n*. When the chuck is at rest any motion of the lever *b* will cause the internal gear *e* to revolve the spider pinions *n*, and this will turn the gear *t* and its cam-plate *o* and move the chuck jaws.

When the lathe is operating, the spider pinions *m* and *n* revolve at the same rate and have no action on the cam-plate *o*. Then, by moving the lever *b* forwards, the speed of pinions *n* is made greater than that of pinions *m*, and this increase acts through the hub gear *t* and cam-plate *o* to close the jaws. In case the lever *b* is moved backwards, the speed of pinions *n* is decreased, and this action through the gear *t* and cam plate *o* opens the jaws. Thus, by changing the speed of the spider pinions *n* from that of their mates *m*, the jaws will be moved when the lathe is running. The chuck is lubricated by grease through the hole *u* in the back plate *h*. Chucks of this type have more wearing parts than standard chucks.

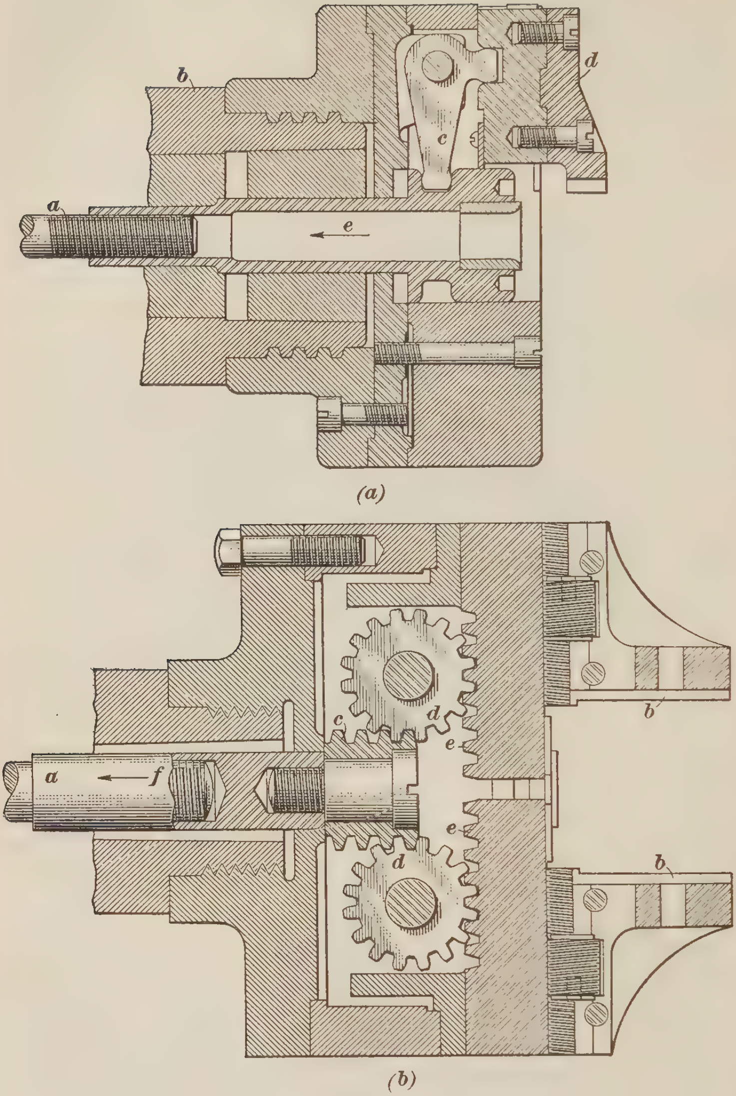


FIG. 38

71. Air-Operated Chuck.—The operating mechanism of one jaw of an air-operated three-jaw chuck is shown in Fig. 38 (*a*). Air pressure is exerted on a piston in a double-acting cylinder fastened to the headstock frame at the outer end of the spindle. The movement of the air piston is transmitted to the chuck by means of the piston rod *a* that reaches through the lathe spindle *b* to the radial arm of a bell-crank *c* inside the chuck. The horizontal arm of the bell-crank engages the back of the jaw *d*. Each jaw has a bell-crank arranged like the one shown at *c*.

When the jaws are to be closed, compressed air is admitted to the end of the cylinder that will pull the rod *a* outwards in the direction of the arrow *e*. The air pressure must be kept on while the work is being machined. Releasing the air lets the work drop out of the chuck. In most cases the work can be changed without stopping the machine.

A two-jaw air chuck is shown in Fig. 38 (*b*). The motion of the piston rod *a* is transmitted to the jaws *b* by a circular rack *c* attached to the end of the rod and engaging two pinions *d*, which mesh with a rack *e* on the back of each jaw. The jaws are closed by the rod *a* pulling in the direction of the arrow *f*.

72. Magnetic Chuck.—In Fig. 39 (*a*) is shown one form of magnetic chuck, and in (*b*) is seen the inside of the chuck body, with the back cover-plate removed. The work is held against the face of the chuck by the magnetizing force of a number of poles *a* inside the chuck. These poles are energized by an electric current through coils *b* surrounding them. The poles are spaced so as to insure uniform holding power over the face of the chuck. The current is led from a direct-current supply to two brushes in the holder *c*, which bear against two contact rings *d* and *e* at the back of the chuck, and insulated from each other as shown in (*c*). The ends of the coils *b* are connected to the rings *d* and *e*, and thus by closing a switch the chuck is instantly magnetized. When the current is turned off the chuck becomes demagnetized, and the work either drops off or it can be easily detached from the face of the chuck.

73. Revolving-Jaw Chuck.—Chucks of the revolving-jaw type are used where the work, such as valves, pipe fittings, etc., requires similar operations at two or more locations around it. Thus, the revolving-jaw chuck shown in Fig. 40 is holding a small globe valve body that requires facing, boring, and threading in its three openings *a*, *b*, and *c*, which

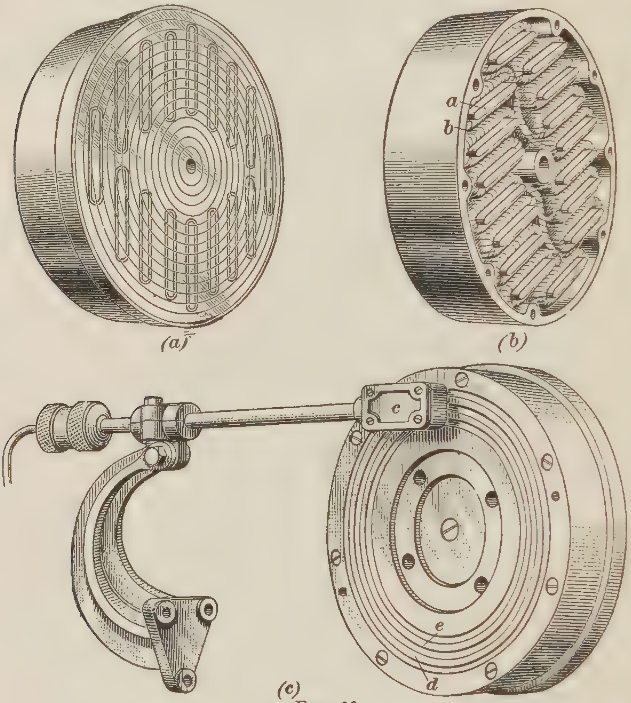


FIG. 39

are 90° apart. The jaws *d* have attachments *e* made to fit the form of the valve. Also, the jaws are supported on trunnions that extend through the pedestals *f*, thus making the jaws free to revolve. On the outer end of one trunnion is a heavy index plate *g* notched to give the spacing required on the work—in this case four equal, or 90°, spacings. The index plate holds the work in its position for machining by means of a key *h* set into a notch and clamped by a thumbscrew *i* between two lugs on the pedestal.

The two pedestals *f* are fitted to slide along the base *j* that has a socket screw *k* for spacing the pedestals and clamping the jaws against the work. The chuck is attached to a face plate on the lathe by the use of two capscrews that pass through the face plate from the back and thread into the holes *l* of the base plate *m*.

74. Selection of Chucks.—If the hole to be bored has the same center as the outside of the work—that is, is concentric with the outside of the work—the universal chuck

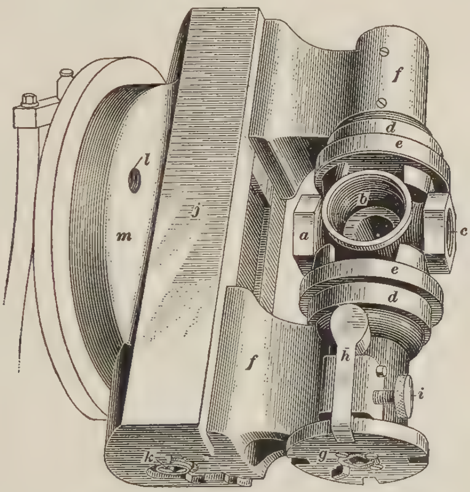


FIG. 40

can be used. If the work does not run satisfactorily, it can be partly turned around in the chuck, and tried in various positions. If this is not sufficient to make the part to be bored run sufficiently true, pieces of paper or brass can be placed between a jaw of the chuck and the work. When this amount of trouble is necessary, an independent chuck would be the better one to use.

75. Mounting Chuck on Lathe.—In putting a chuck on the lathe, its thread and that on the spindle should be cleaned and oiled, then it should be held carefully against the nose of the spindle while the belt is pulled by hand and the screw

draws the chuck up against the shoulder. It is not good practice to start the lathe by power and hold the chuck against the spindle, expecting the thread in the chuck to catch squarely on the spindle thread; neither is it good practice to let the spindle screw into the chuck up to the shoulder with a bang. This often causes the chuck to stick so tightly to the spindle that it becomes difficult to remove. When the chuck does stick on the spindle, it may be loosened by standing a block of wood on the back **V** and allowing a jaw of the chuck to come down on this block. The lathe is then put on the slowest speed, and run backwards by hand, which loosens the chuck; one or more quick raps of the jaw on the block will aid greatly.

76. In the case of a motor-driven lathe, where there is no belt to turn the lathe by hand, means are usually provided for turning the spindle by hand. If not, the chuck should be started on the spindle by turning it by hand until it is certain that the threads are not crossed, even though it may be necessary to employ a helper. Large chucks are lifted into place by means of a crane or hoist. The chuck is hung so that its face is vertical and the hole is in line with the spindle. Then, with one man at the back of the chuck and another holding the chuck at the front, a third man handles the shipper and starts the lathe slowly. The two men can get the chuck started squarely on the thread.

Medium-sized chucks may be rolled up a plank and into position in line with the spindle. The chuck should rest on a plank across the **V**'s, and a plank of the proper thickness selected to bring the center of the chuck level with the spindle center. Once a plank is cut to fit a chuck, it should be marked and always kept at hand.

77. Care of Chucks.—Chucks should not be hammered, nor should a piece of pipe be used as an extension to the chuck wrench to give greater leverage; in either case the chuck may be sprung or broken. In gripping a large piece, the jaws should not be run out so far that only a small part of the thread holds on the screws, as the threads may be damaged, and the body of the chuck may be sprung. When

a chuck is to be mounted, the lathe centers should first be taken out of the spindle.

78. Solid Mandrel.—A lathe mandrel is a short centered shaft that is placed on the lathe centers to support work which has a hole through it and cannot be centered of itself. Mandrels are made in several forms, such as solid, expanding, conical, threaded, etc. The term *arbor* is sometimes applied to a mandrel, but this term more strictly denotes the shaft or holder on which a circular saw or a milling cutter is placed, and by which it is driven.

A solid mandrel is commonly used on work having a bore 3 inches in diameter or less. The best form is made from tool steel, hardened and tempered, such as that shown in Fig. 41. It is made slightly under size at the ends, so that the dog may be put on. Flat spots are milled on the ends to give the screw of the dog a good seat.

FIG. 41

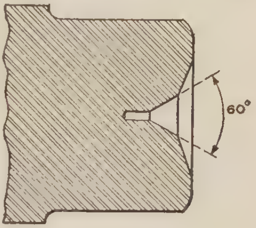


FIG. 42

79. Center Holes in Mandrels.—The center holes should be protected by a countersunk opening, as shown in Fig. 42, so that they will not be injured when the end of the mandrel is struck by the hammer while it is being driven into the work. The center hole should have a taper greater than 60° at the opening, then if the mandrel gets bruised on the end from any cause, there will be less danger that the 60-degree part of the hole will be thrown out of true. To preserve the center holes further, the mandrel is hardened. The center holes should be made with great care, the angle being 60°, so that they will exactly fit the lathe center, and the hole should be deeper than the tapered part. In the best mandrels, the center holes are lapped true after hardening. The central portion of the mandrel is carefully ground to size, and made slightly tapered.

80. Truing Mandrels.—The small end of the mandrel is generally about the exact size, but the large end is from .002 to .003 inch larger, depending on the length of the mandrel and the length of the work to be turned. The taper of mandrels may be from .005 to .01 inch per foot. The large end is distinguished by having the size of the mandrel stamped on it. Mandrels are ground to standard sizes and should fit holes reamed with standard reamers. The necessity of keeping them true may readily be seen when a pulley or similar piece is to be turned true with a part that has been bored and reamed. If the mandrel is untrue, the hole will run untrue as the work revolves. The rim or part of the work being turned will be cut true with the machine, but will not be true with the bore. When the finished pulley is placed on a shaft that runs true, the rim of the wheel will wabble. It may be seen that an untrue mandrel will always produce untrue work and lead to a great deal of trouble. Mandrels may become untrue from the wear of the center holes, and from the springing of the body of the mandrel when driven into a crooked hole, if the hole is long and the mandrel slender; or by taking too heavy a cut on the work for which they are used.

81. Cast-Iron Solid Mandrel.—When solid mandrels of large size are to be used, they are sometimes made of cast iron. The ends of such a mandrel are drilled, and steel plugs are fitted for the center holes. The plugs are hardened after the center holes are correctly made, and are driven or screwed into the cast-iron body. When cast-iron boring bars are made, it is better to use hardened-steel center plugs.

82. Care of Centers of Mandrels.—When the mandrel is placed on centers, the dead-center hole should be well oiled, and the center run carefully into the hole. It is so adjusted that the mandrel will turn freely between centers without lost motion. If the work or the mandrel heats, the pressure due to the expansion will force the oil out of the center hole, causing the center to heat and squeak. At the first sugges-

tion of squeaking, the lathe should be stopped, the center slacked off, well oiled, and readjusted to working conditions.

83. Putting Mandrels in Work.—When a mandrel is put in a piece of work, it is usually driven in. The hole and the mandrel are coated with oil to keep the surfaces from cutting, and, while the work is well supported on the driving block, the mandrel is driven in with a mallet or soft-faced hammer. Hard-faced hammers should never be used for driving mandrels. Babbitt or rawhide-faced hammers are the best. If the work is small, much driving is unnecessary. If the pieces fit well, it will take but little pressure to force the mandrel into the work sufficiently to keep it from slipping. The practice of driving a mandrel as long as it can be moved is bad. After a mandrel is driven into the work with a soft-faced hammer, the center hole should be carefully cleaned before the work is put between the lathe centers. Dirt in the center holes of a mandrel has the same result in making work untrue as untrue lathe centers.

84. In driving a mandrel, care should be taken to strike fair blows on the end, as untrue blows are liable to spring it. Mandrels fit best when driven in from the large end of the hole in the work. Most reamed holes are slightly larger at the end of the hole at which the reamer entered, because the reamer acts longer in the starting end of the hole, and thus scrapes off more metal. This enlargement is especially pronounced in hand-reaming and where the reamer is not passed clear through the hole. It is present in almost every reamed hole with the exception of those which are ground.

When both roughing and finishing cuts are to be taken by the lathe tool, and a separate mandrel is used for each cut, the roughing mandrel is sometimes driven in from the small end of the hole, as this stretches the small end and makes a more nearly parallel hole. The finishing is best done with the finishing mandrel driven in from the large end of the hole.

85. Mandrel Press.—A better way of putting mandrels in the work than by driving, is by the use of a mandrel press,

which is operated either by hand or by power. In Fig. 43 is shown a style of hand-operated mandrel press. It consists of a heavy cast-iron frame, in which is fitted a plunger *a* that is operated by the hand lever *b*. When the mandrel *c* is to be pressed into the work *d*, the mandrel and the work are brought under the plunger so that the mandrel may be forced in with a direct, uniform pressure.

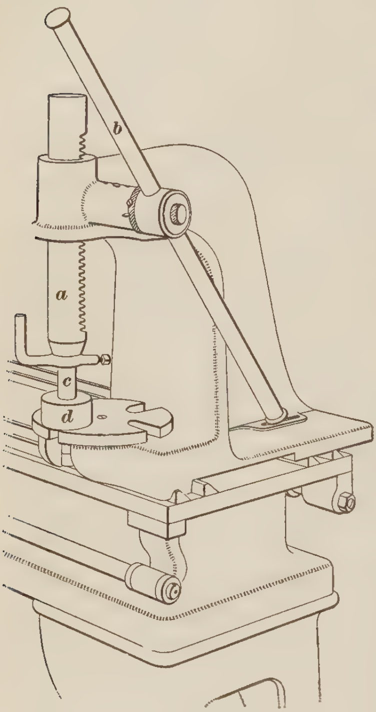


Fig. 43

86. Heavy Cuts on Light Mandrels. — Very often a mandrel is sprung by taking too heavy a cut. This is particularly true if the work is large. For small work, the mandrel will have sufficient friction in the work to drive it so that a dog may be put on the mandrel; but if the work is large and the bore is small, the mandrel will not have sufficient friction to drive it. The mandrel can then be used only to support the work, while the driving should be done by a pin or a stud on the face plate. When the work is thus driven, it is possible to take heavy cuts; but if a deep, heavy cut is taken on the outside of a large piece supported on a small mandrel, the side thrust of the tool will act with such a leverage on the work that it will spring the mandrel. Light cuts, therefore, must be taken. When cutting close to a mandrel with a side tool, as is the case when facing hubs or similar work, care should be taken not to cut into the mandrel. The mandrel may be hardened, but it is not harder than the tool point.

87. Expanding Mandrel.—Although the hardened solid steel mandrel is the best form, some inconveniences arise from its exclusive use. In order to be prepared for all sizes of work, a very large stock of mandrels would be necessary. This leads to inconvenience in some shops, while in other shops it is beneficial. Shops doing a great variety of work, where all sizes of holes are bored, demand a mandrel that can be adjusted to slight differences of diameter. Shops that are making a particular line of work, where many pieces are turned to the same size, are benefited by using the solid mandrel; *first*, because it is more accurate in itself; and, *second*, it acts as a second check-gauge on the work. If a piece that has been bored too large gets into the lot, it cannot be finished,

Fig. 44

since the mandrel will not hold the work. When the cost of keeping a lot of mandrels up to a standard size is considered, the type of mandrel that will expand within certain limits and fits all sizes of holes within these limits is much cheaper than a great stock of solid mandrels.

88. Tapered-Pin Expanding Mandrel.—An expanding mandrel, consisting of a tapered part *a* that fits into a tapered split-bushing *b*, is shown in Fig. 44. The bushing is ground round and parallel on the outside. As the tapered mandrel is driven into the work and the bushing, the latter expands, thus filling the hole. The method of splitting the bushing as here shown allows it to spring and expand evenly within a quite wide range of limits.

89. Multiple-Jaw Expanding Mandrel.—Another form of expanding mandrel is shown in Fig. 45. It consists of a steel mandrel that has been centered with the same care found necessary in solid mandrels. Four rectangular grooves are cut along its sides, these grooves being cut deeper at one end than at the other. A sleeve *s* fits loosely over the mandrel

and has slots cut in its sides which come opposite the grooves cut in the mandrel. A hardened-steel jaw slides loosely in each groove and slot. As the sleeve moves along the mandrel

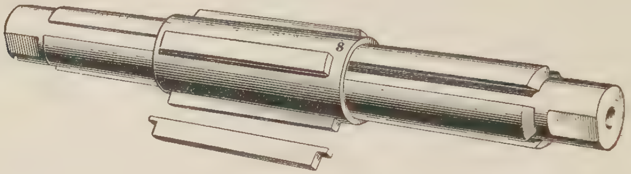


Fig. 45

it carries the jaws with it, and, because of the varying depths of the slots, the jaws are moved in or out, according to the direction in which the sleeve is moving on the arbor. With this type of mandrel, different sets of jaws of different heights may be used, which will give it a range for different sizes of holes. When the work is thick enough to be stiff, so that it cannot be sprung, these mandrels are very convenient; but there is danger of springing the work, due to the outward pressure of the four jaws. Care must be taken always to replace the jaws in the slots they come out of.

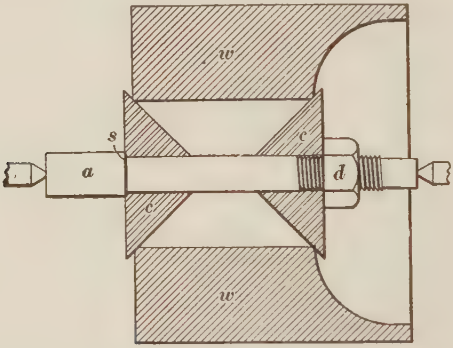


Fig. 46

90. Cone Mandrels.—For some classes of work, a cone mandrel, as shown in Fig. 46, is used. It consists of the central part *a*, to which are fitted two cone-shaped pieces *c*. One piece is held from sliding along the mandrel by the shoulder *s*. The work is placed between the cones, and the

second cone is tightened against the work *w* by the nut *d*. The cones are kept from turning on the mandrel by keys. This is a very convenient way of holding work that does not require great accuracy in being turned.

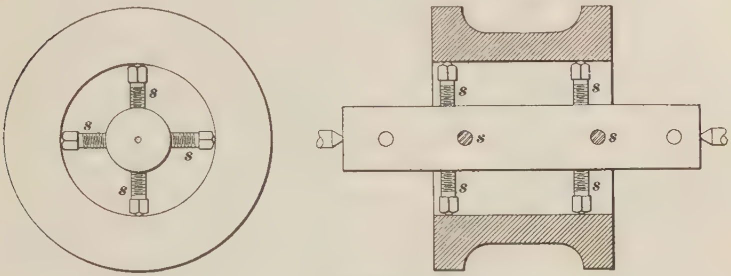


FIG. 47

91. Special Expanding Mandrel. — Another form of mandrel for carrying bored or cored work that is being turned and faced is shown in Fig. 47. A heavy bar is drilled and tapped so that screws may be put in square with the bar, as shown at *s*. The circles around the bar in which the screws are placed are at such a point that the screws come near each end of the work. The work is adjusted and held in place by unscrewing the screws from the bar, thus bringing the pressure on the heads of the screws.

92. Mandrel for Threaded Work.—After short work, such as a special nut, is tapped it is sometimes faced true

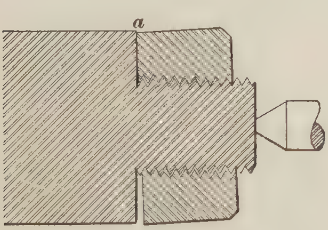


FIG. 48

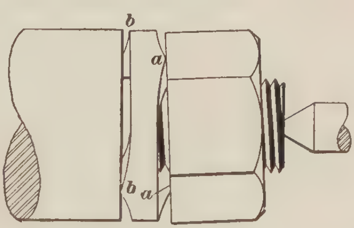


FIG. 49

with the thread. A mandrel for this work is shown in Fig. 48 with the nut in place. If the nut has not been tapped squarely, or if it fits loosely on the mandrel, it will first come against

the shoulder at one side, as at the point *a*. As soon as this point touches, the nut will be rocked on the thread so that the axis of the nut thread will not be parallel to the axis of the mandrel. If the nut should be faced while in this position, the face would not be true with the tapped thread.

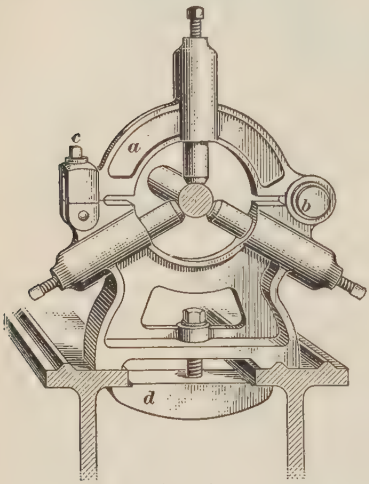


Fig. 50

93. To overcome this difficulty, an equalizing washer, Fig. 49, must be put between the shoulder of the mandrel and the nut, so that the nut cannot be thrown out of line, but will be held back squarely against the threads. On one face of the washer are two projecting points *a* diametrically opposite each other. On the other face of the washer are two other points *b* diametrically opposite, but quartering with those on the first side. When the nut is screwed against the washer thus supported, it is free to rock in any direction, with the result that it centers itself with its threads, and not with the face of the mandrel.

94. Steady and Follow Rests.—Attachments for supporting work in the lathe are shown in Figs. 50 and 51. In Fig. 50 is shown a *steady rest* and in Fig. 51 a *follow rest*. The steady rest may be located at any required point on the lathe bed to support long, slender work held between centers, or where one end of the work is held in a chuck and the other end is being bored. The frame *a* is hinged at *b*, thus allowing the upper half to be swung back for inserting or removing the work. The bolt clamp *c* locks the frame in the closed position. The lower part of the frame is held to the lathe bed by an anchor *d*, bolted against the under side of the **V**'s. One leg of the steady rest has a **V** cut to hold its

jaws square with the line of the lathe centers; the other leg is flat and rests on the top of the back **V**. The jaws are adjusted so that the work turns freely but without play.

The follow rest, Fig. 51, is mounted on the carriage and always maintains its same position opposite the tool, and prevents the work from springing backwards or upwards owing to the pressure of the tool. It consists of a split frame having grooves *a* inside the lower ends to fit over the edges of the saddle. A clamping bolt *b* is used to grip the frame to the saddle. The work supports *c* and *d* each have supporting screws *e* and *f*, and also setscrews *g* and *h* to prevent the supports *c* and *d* from falling out of the frame.

95. Form of Jaws of Steady Rest.—The points of the steady-rest jaws are sometimes left rough and flat by the manufacturer, the user having to finish them to suit his work. It is well to make the radius of the points equal to or larger than that of the work to be supported. Thus, in Fig. 52,

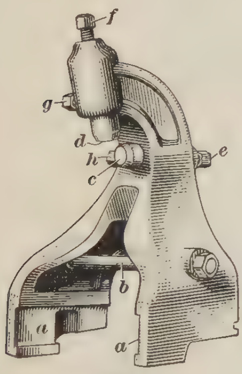


FIG. 51

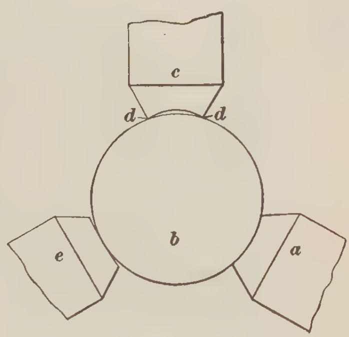
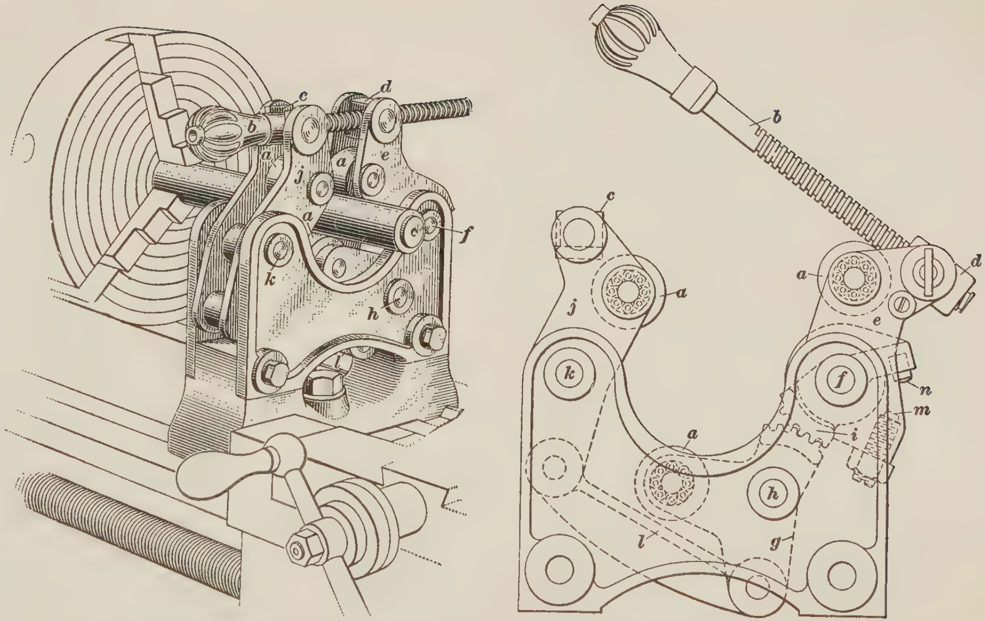


FIG. 52

the point *a* has the same curvature as the work *b*. The point at *c* has a shorter radius than the work *b*, so that the sharp edges *d* may dig into the work. The point at *e* has a larger radius than the work *b* and gives good support, but the point at *a* is better. The points may be finished to the desired curvature by the use of a boring bar, but ordinarily the finishing of the points is done by hand-filing.



(a)

(b)

Fig. 53

96. Roller Type of Steady Rest.—In order to minimize the wear from the high pressure on the jaws of the steady rest when high-speed steel-cutting tools are used, a roller type of rest shown in Fig. 53 is sometimes used. It has three hardened and ground rollers *a* mounted in roller bearings that grip and center the work as the arm *b* is pulled down and locked in its seat at *c*. The rest is tightened by screwing the lever *b* into the nut *d*.

By pulling the handle *b* down, the link *e*, pivoted at *f*, operates an arm *g*, pivoted at *h*, through the gear segments *i*. In like manner the arm *j*, pivoted at *k*, is operated by the

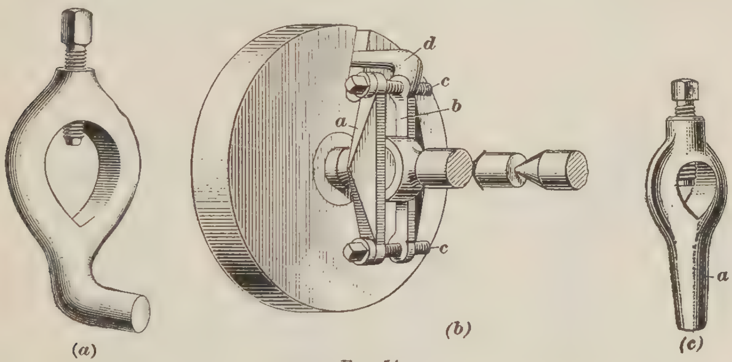


Fig. 54

arm *g* through the connecting lever *l*. This causes the three rollers *a* to come toward the center at the same time.

When the work is inserted and handle *b* pulled down, the link *e* does not operate the gear segment *i* until the adjusting screw *m* strikes the stop *n*. This widens the space available for the work, as the other two rollers are not brought into position until the gears at *i* are operated.

97. Common Style Lathe Dog.—A lathe dog, known also as a *carrier* or *driver*, is a device that is slipped over and clamped to the end of a piece of work. A tail, or projection, on the dog enters a slot in the face plate, or engages a stud projecting from the face plate, and the work is thus caused to rotate. The bent-tail dog shown in Fig. 54 (*a*) is com-

monly used for round work. It is a steel forging, or malleable casting, with a hole to receive the end of the work and a setscrew to clamp it tightly. The bent end, or tail, enters a slot in the face plate. The clamp dog shown in (*b*) consists of two parts *a* and *b* that may be drawn together by the screws *c*, to clamp rectangular work, or work with a flat end, as shown. A tail *d* on the part *b* serves to drive the work. The straight-tail dog shown in (*c*) requires a stud to be fastened to the face plate so as to engage with a tail *a* and rotate the work.

98. Safety Style Lathe Dog.—To avoid the danger to the operator from the exposed setscrew heads as used on the

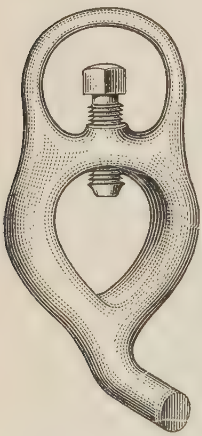


Fig. 55

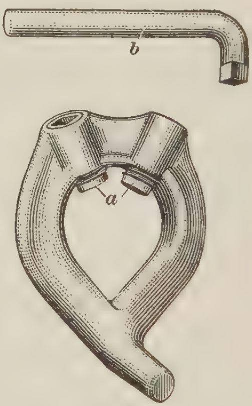


Fig. 56

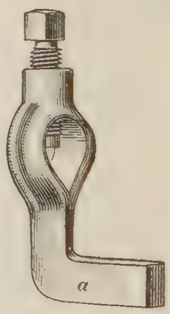


Fig. 57

lathe dogs shown in Fig. 54, a curved guard, surrounding the setscrew and forged solid with the body of the dog, is sometimes provided, as shown in Fig. 55. In Fig. 56 is illustrated a lathe dog with setscrews *a* that have no projecting heads. A square-end wrench *b* that fits the hollow outer ends of the setscrews is used to clamp the dog to the work. For light service the dog is made with a single setscrew.

The dog having a flat bent tail of the same thickness along its whole length, as shown in Fig. 57, is used for driving

tapered work, as the tail *a* can slide back and forth in the slot on the face plate with the same fit from end to end. The thick end of the tapered tail on the ordinary dog is liable to bind in the slot and the small end gives too much *clearance,* or *backlash,* when tapered work is turned.

SPECIAL FORMS OF ENGINE LATHES

TOOLMAKERS' LATHE

99. General Description.—The term toolmakers' lathe is applied to lathes of the form shown in Fig. 58, having from 10 to 16 inches swing. In appearance it is similar to the regular screw-cutting engine lathe, but it is made with a

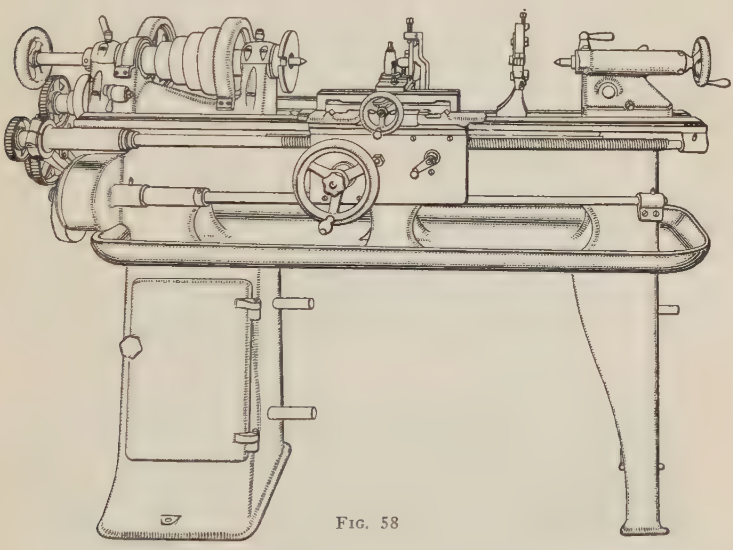


FIG. 58

greater degree of refinement than the ordinary engine lathe and is usually fully equipped with various attachments, such as the taper and relieving attachments, compound rest, and special chucks, to handle all classes of toolroom work. The screws and dials of such attachments are graduated either in the inch or in the metric system.

The carriage of the lathe shown in Fig. 58 has a rest of the rise-and-fall type, which has the advantage of being more quickly adjusted for height of tool and for turning to size than the rest commonly used.

100. The live spindle of the toolmakers' lathe is shown in Fig. 59. The nose is threaded, as shown at *a*, and the

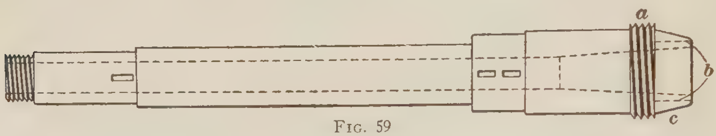


FIG. 59

remainder is turned parallel, as indicated by the dotted lines *b*. A conical bushing *c* is placed on the parallel part and the face plates and chucks are bored tapering to fit the tapered bushing. The advantage of this construction is that the face plate is drawn up tightly by the thread against the taper on the bushing, which centers the face plate or chuck very accurately and holds it rigidly.

The larger sizes of toolmakers' lathes are provided with gear-box feeds, with carriages of the gib form, and with motor and geared-head drive, as may be required.

101. Holding Devices.—The work, when not placed on the centers, as in the case of bar stock, is forced to revolve by the spindle by the use of *draw-in*, or *draw-back, collets, chucks,* and *arbors*. A draw-back collet is shown in Fig. 60,

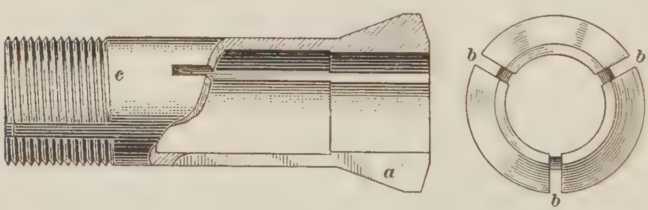


FIG. 60

and the method of attaching it to the lathe spindle in Fig. 61. The collet has a tapered end *a*, Fig. 60, that has three splits *b*, so that the end can be closed in and grip the work, and the

other end is threaded, as shown at *c*. A long tube *a*, Fig. 61, extends all the way through the bore of the spindle. The

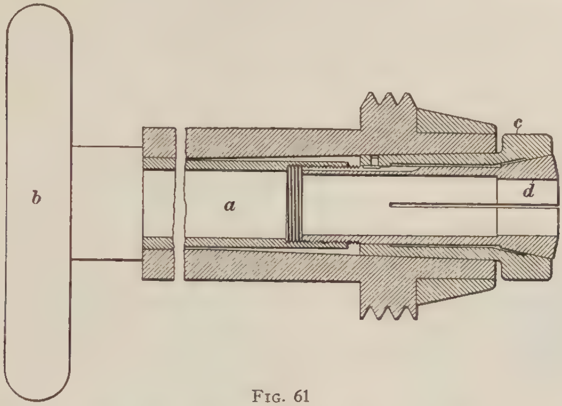


FIG. 61

outer end of the tube has a hand wheel *b* and the inner end is threaded internally. A hardened and ground bushing *c* fits

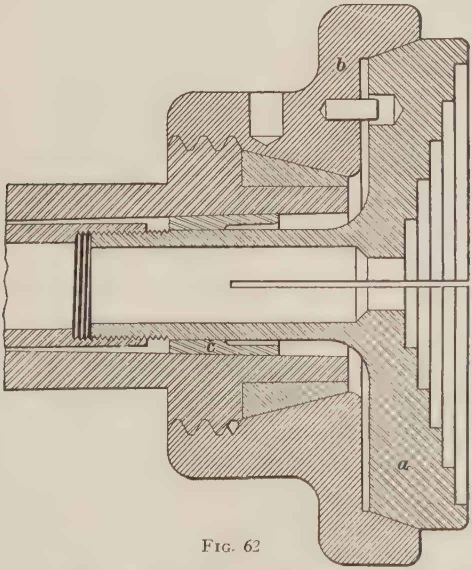


FIG. 62

into the spindle nose and the collet *d* is placed in this bushing. By screwing the tube *a* on the thread of the collet by

means of the hand wheel, the collet is drawn into the end of the spindle, thereby forcing the end of the collet to a smaller diameter and to grip the work. The bushing *c* is made with the same taper as the taper of the spindle, and is known as the *closer*, or *adapter*.

102. Step Chuck.—A form of step chuck operating in a similar way as the draw-back collet is shown at *a* in Fig. 62. The step chuck is used for facing thin pieces of large diameter and in cases where a finished piece must be held true. The adapter *b* screws on the end of the spindle and there is also a sleeve *e* placed in the bore to guide the chuck. Some step chucks are fitted with adjustable jaws, and various designs are used.

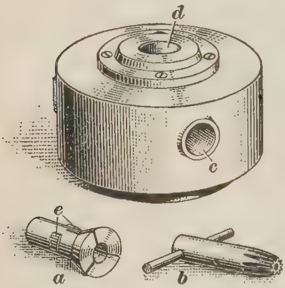


FIG. 63

In Fig. 63 is shown a draw-in chuck for the collet *a*. The chuck is operated by the key *b* applied in the hole *c*. The chuck is screwed onto the spindle and the collet is inserted in the hole *d*. The pinion on the key *d* engages a bevel gear in the chuck, which in turn engages a rack and draws in the collet. The chuck is thus operated directly without the use of a pull rod through the lathe spindle. The collet is attached to the rack by means of the short flat body projections *e*.

BENCH LATHES

103. Construction of Bench Lathe.—When small work must be finished with considerable accuracy, the ordinary engine lathe is too large and clumsy. Therefore, the bench lathe, or precision lathe, Fig. 64, may be used to finish this class of work. It is fitted with a double slide rest having automatic feed. The slide rest may be removed and other attachments substituted for special milling, grinding, or hand-tool and drilling operations. For cutting threads, a chaser bar is provided.

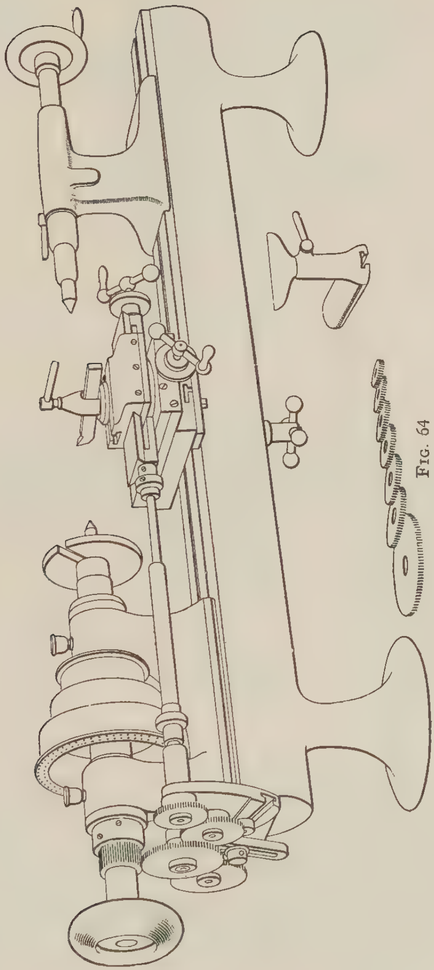


Fig. 64

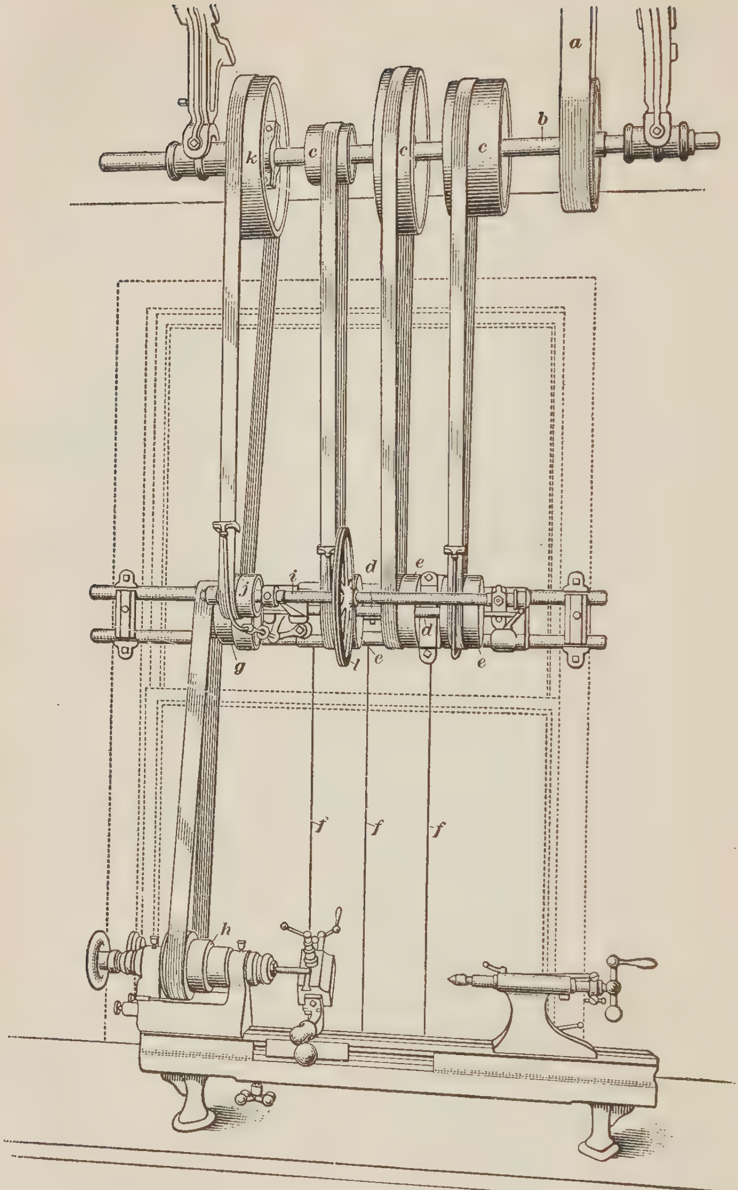


Fig. 65

104. Draw-in collets are used instead of the chuck furnished on larger lathes. These collets are intended to hold smooth, round stock, such as drill rod, cold-rolled steel, brass rod, and finished work, and should not be used to hold rough stock or stock that is not round. The tail-stock of the lathe shown in Fig. 64 has no set-over, and provision for turning a taper is made by setting the top slide of the compound rest to the given angle or taper to be turned. A train of change gears on the head is provided for feeding and thread cutting. The large cone-pulley flange is drilled with a number of index circles to be used for direct indexing, in cutting small gears or cutters or for dividing circles. The spindle is held stationary during a cut by a pin that passes through a bracket on the head and enters any required hole in the selected index circle.

105. Driving of Bench Lathe.—The bench lathe should be secured firmly to a rigid bench facing a window where a good light can be had, as in Fig. 65. It is usually driven by a belt *a* from the main shaft to the jack-shaft *b*, which carries a number of pulleys *c* of different diameters to give the necessary countershaft speeds. A countershaft *d* is held in brackets on a frame secured to the wall midway between the lathe and the jack-shaft, and on it are a pair of tight and loose pulleys *e* corresponding to each driving pulley on the jack-shaft.

A shifter operated by a wire *f* is used to move each belt from the loose to the tight pulley to be used for any required countershaft speed. The countershaft also has a cone pulley *g* for varying the spindle speed of the lathe in connection with the cone *h*. A second shaft *i* is provided on the countershaft hanger and is driven through the pulley *j* by the large pulley *k* on the jack-shaft. The shaft *i* carries a grooved pulley *l* that is used to drive a grinding attachment clamped on the slide rest.

AXLE LATHE

106. Car axles may be turned on an ordinary heavy-duty engine lathe; but the work may be done much faster on an axle lathe, such as is shown in Fig. 66. The lathe is so designed that the two ends of the axle may be turned to the correct journal dimensions at the same time, which is accomplished by placing the driving head a in the center of the lathe bed. The head has an opening through it to permit the passage of the axle and is equipped with a plate for engaging the driving dog. Two tools b and b_1 are used, and the journals can be turned simultaneously without being hampered by any driving device. The driving head is operated by gearing connected by a shaft with the cone pulley c. Two tailstocks d and d_1 are adjustable along the bed to suit different lengths of axles. The tailstock d has a fixed center, and the tailstock d_1 has a center moved in or out by the hand wheel e. The axle f, shown in place in the lathe, is handled by the overhanging crane g, or by a power-operated hoist.

107. After the work is adjusted between the centers h and h_1, the dog or driver is put in place. An equalizing dog or a two-tailed dog operated by an equalizing device should be employed, so that the driving force will not spring the axle. Chucks cannot be used to drive the axle, as they spring the work. A stream of soda water flows through pipes i and i_1 on the tools during the cut. When high-speed steel tools are used, the lathe is of heavier construction than shown and usually motor-driven.

WHEEL LATHE

108. A lathe designed for turning locomotive driving wheels after they have been pressed on to an axle is shown in Fig. 67. It has two driving heads and two tool rests, thus enabling the operator to turn both driving wheels at the same time. The left-hand headstock d is fixed, but the right-hand headstock d is movable to permit of setting and releasing the work. Each main spindle has a large face plate c. The face

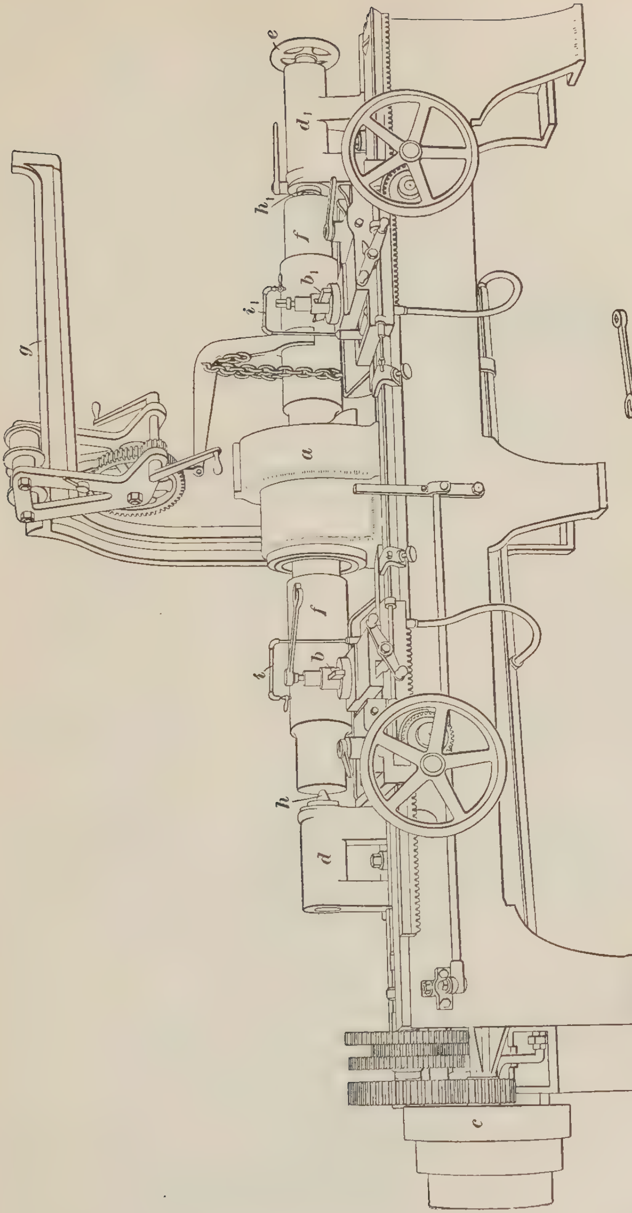


FIG. 66

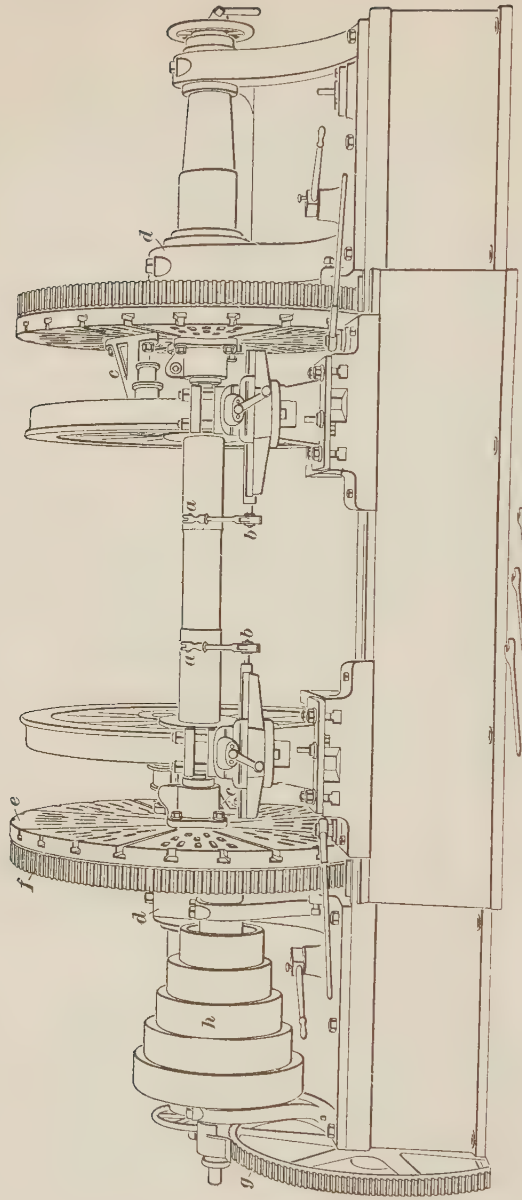


FIG. 67

plates are driven by the spur gears f meshing with pinions, not shown, on a heavy shaft extending along the length of the bed and driven by the gear g that in turn is driven by the cone pulley h through a pinion.

There are no feed-rods along the bed to operate the tool carriages, as found in ordinary lathes. The tool carriage ordinarily used is similar to the compound rest, and it may be turned on its base and set at any angle. Two slides allow

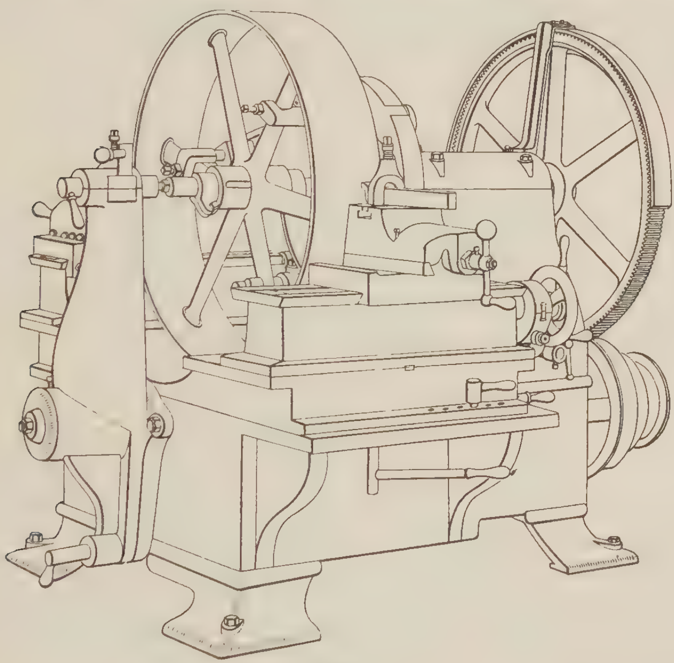


FIG. 68

the tool to be moved in two directions, at right angles to each other. Screws for moving the slides are operated by a lever a connected to the feed-screws by ratchets b. These levers are moved automatically by levers and cams in a separate mechanism above the lathe, to which they are connected by chains.

109. After the wheels on the axles are put between the centers in Fig. 67 the drivers c shown on each face plate are so

adjusted against each wheel that it is driven from its face plate. These lathes may also be used for boring the tires of locomotive driving wheels, the tires being bolted to the face plates and bored and faced, as in ordinary face-plate work. This method of boring tires is seldom employed, as they can be bored much better on a vertical boring mill. Driving-wheel lathes intended for the larger and heavier wheels are set so that the top of the bed is level with the floor, which allows the wheels to be rolled in and out without unnecessary hoisting. They are of very rigid construction and are usually driven by motors.

PULLEY LATHE

110. A type of lathe specially designed for turning pulleys is shown in Fig. 68. The lathe has two tool rests so that two tools may be used, one at the front and one at the back of the machine. Special driving dogs attached to the face plate drive the pulley by its arms.

HAND LATHE, OR SPEED LATHE

111. Description.—Hand lathes or speed lathes are the smaller sizes of lathes used for drilling and such other operations as can be performed with tools held in the hand, or for operations that require a higher speed of work than can be obtained by the ordinary turning lathe. These lathes are without back gears or slide rests. Fig. 69 shows a standard type of hand lathe. It is mounted on a table, which makes a convenient place for holding tools and work.

112. Uses of Hand Lathe.—Work that is of irregular outline, requiring the use of hand tools, is often finished on the hand lathe. A small chuck fitted to the spindle of the lathe is very convenient for turning or pointing small rods and pins, and a variety of similar work. Drilling may also be done very readily on certain classes of work. When much drilling is to be done, a tailstock with a lever attachment for

feeding the spindle is more convenient than the screw attachment. One of the principal uses for which the speed lathe is adapted is the polishing of cylindrical work; also the process

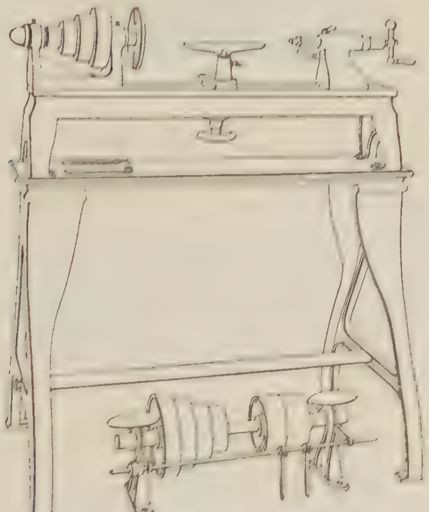


Fig. 69

of forming various sheet-metal shapes, known as metal spinning.

113. Special Centers.—When the hand lathe is used for drilling or reaming center holes, the drill is held in a chuck and the work is fed against the drill by the tailstock spindle. If holes are to be drilled in thin flat pieces, a pad center,

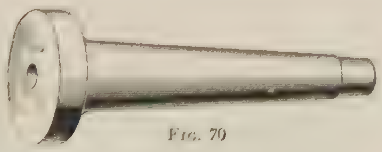


Fig. 70

Fig. 70, can be used in place of the cone center. If holes are to be drilled diametrically through rods or tubes, a *forked center*, Fig. 71, aids in holding the work central.

114. Hand Slide Rest.—A hand slide rest that is often used on the hand lathe is shown in Fig. 72. The ordinary

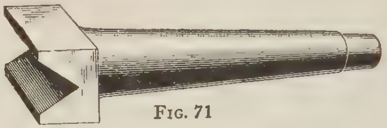


Fig. 71

hand rest is removed and this one is clamped in its place. A small tool can be held in the tool post, and for light work it is very convenient.

GAP LATHE

115. A style of lathe often seen in shops where large lathes of considerable swing are seldom needed, is the gap lathe, shown in Fig. 73. Its principal feature is the second

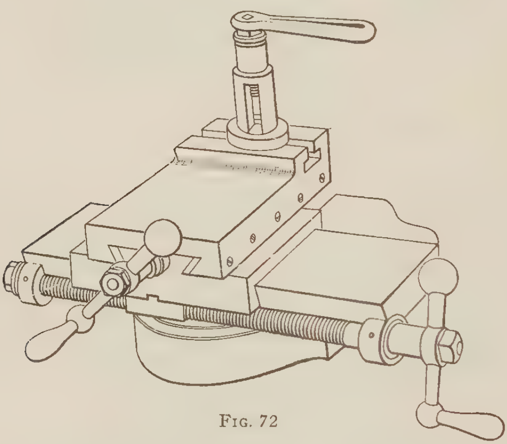


Fig. 72

bed *a*, which slides on the main bed *b*. When ordinary work is to be turned, the top bed is moved up very close to the face plate, nearly closing the gap *c*. It is then used as an ordinary lathe. When a particularly large piece is to be turned, the upper bed is moved away from the headstock by turning the hand wheel *d*, thus opening the gap *c* and giving the lathe its full swing over the main bed *b*. The lead screw *e*

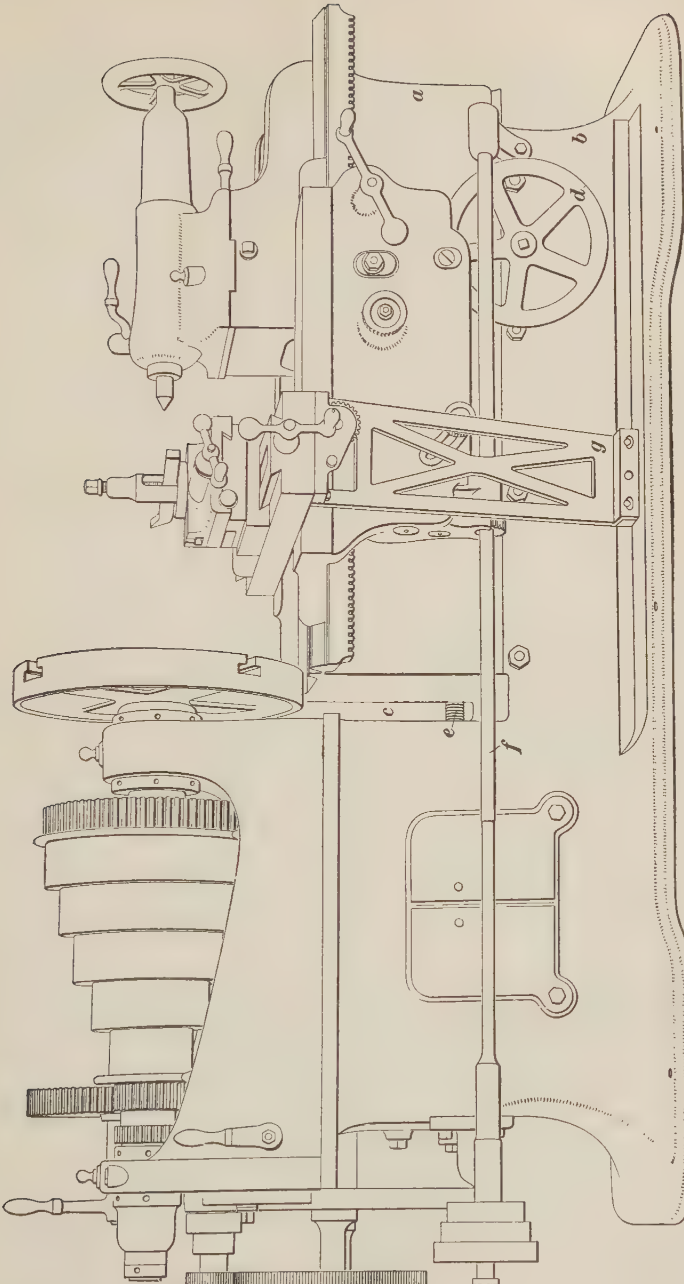


Fig. 73

is at the back near the bottom of the gap, and the feed-rod *f* is at the front. Some gap lathes have the lead screw in front, and the screw serves also for a feed-rod. The tool in this type of lathe can operate a considerable distance out on the cross-slide. The bracket *g* is provided to support the overhang of the cross-slide.

ENGINE LATHE TOOLS

THEORY AND FORMS OF LATHE CUTTING TOOLS

THEORY OF LATHE CUTTING TOOLS

CUTTING PROPERTIES OF TOOLS

1. Requirements of Lathe Cutting Tools.—The lathe tool most commonly used is either ground or forged from bar steel about twice as deep as wide, ranging from 1 inch $\times \frac{1}{2}$ inch for light turning operations, to $2\frac{5}{8}$ inches $\times 1\frac{3}{4}$ inches for heavy cuts. The tool should be heavy enough to cut with the least amount of vibration and to conduct away quickly the heat caused by the cutting. The cutting edge of the tool must be sharp enough to separate the chip from the work by the use of the least amount of power, but it must also be strong enough to cut for a reasonable length of time without being reground.

2. General Theory of Cutting Tools.—The action of a lathe tool in removing a chip or shaving from the work is more a tearing action than a cutting action. Cutting, as done by an axe or a knife, consists in forcing a thin edge *a*, Fig. 1, into the substance to be cut, which wedges or splits away a thin chip. The flat face *b* of the knife presses against the body of the work while the sloping face *c* forces the chip to curl away from the work. Both faces are in contact with the material being cut.

3. The lathe cutting tool acts in a different way from a knife in that only one face, or *flank*, is in contact with the work. Thus, the *front*, or *clearance surface*, *a* of the tool *b*, shown in Fig. 2, does not touch the work *c*. As the work turns against the cutting edge of the tool, a chip is torn from the work and crushed or broken by the top surface *d* into separate sections *e*, *f*, etc. The portion of the chip that is still pressing upon the *top*, or *lip*, surface of the tool, acts as a lever by which the next portion of the chip is torn away from the work.

4. As shown in Fig. 2, the tearing action causes the chip to separate from the work at a point *g* above the cutting edge of

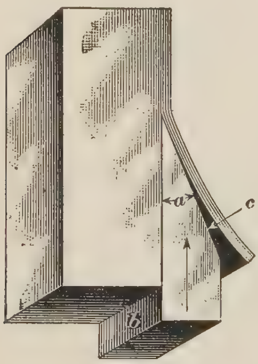


FIG. 1

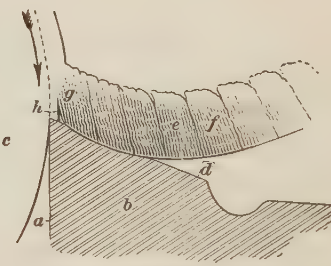


FIG. 2

the tool, and the cutting edge shears off the irregularities *h* left on the work after the chip has been torn away. The pressure of the chip on the lip surface of the tool is much heavier a little distance back from the cutting edge, than on the cutting edge itself, and the friction from the heavy pressure often wears a cavity in the tool. Also, the great heat from the friction sometimes welds the surface of the chip to the tool. There is very little actual contact of the chip with the cutting edge.

In Fig. 3 (*a*) is shown a tool as it is sometimes worn by heavy cuts on hard metals. The cutting edge *a b* has retained its sharpness, but immediately behind it a shallow depression *c* has been worn.

5. Theory of Roughing Tool.—The roughing tool is used to remove the first layer of metal from the work. Usually the roughing cut is as heavy as the tool and lathe will stand. A round-nosed roughing tool, as shown in Fig. 3 (*a*), is the form most frequently used, because it removes the metal in the shortest time, leaves the work fairly true and smooth, and is adapted to a large variety of work. Its cutting action differs from that of a straight-edged roughing tool, in that the thickness of shaving is not uniform as in the case of the latter tool, but thins down at the edge *a*, as shown in view (*b*). The cutting speed can be increased because the

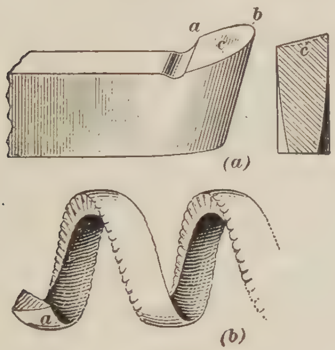


FIG. 3

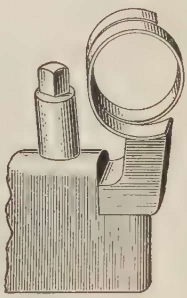


FIG. 4

nose *b*, view (*a*), or that part of the tool that does the finishing, is subjected to less pressure from the chip. The roughing tool with the curved cutting edge is also less likely to chatter than the straight-edged tool. At high speed the excessive friction of the chip on the top of the tool sometimes causes enough heat to weld the chip to the tool, as shown in Fig. 4.

6. For heavy roughing cuts, it is well to make the tool with as large a curve at the cutting edge as is practicable without causing it to chatter. A small curve causes a decrease in cutting speed, because the shaving is not thinned down as much as with a large one. In cutting hard steels and cast iron, the roughing tool should have a large curve.

7. Conditions Influencing Angles of Lathe Tools.—The angles of *top side rake a*, *top front rake b*, *clearance c*, *and keenness d* of the tool, Fig. 5, should be adapted to the kind of metal to be cut, to the hardness of the metal, and to roughing or finishing cuts. The way the tool is set and fed to the work may, however, alter the effect of some of the angles. For this reason, the term *effective angle* is sometimes used in connection with the angles of tools when taken in relation to the work for which they are set. The angle of keenness *d* between the cutting faces of the tool is not changed by the setting, but the rake angles *a* and *b*, and the clearance angle *c* are changed by the setting of the tool.

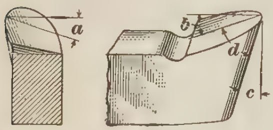


Fig. 5

8. Effect of Height of Tool on Angles of Rake and Clearance.—In Fig. 6 is shown a round-nosed roughing tool at its highest possible cutting position. The line *a b* is drawn from the center *a* of the work through the point *o* of the tool, and the line *c d* is drawn perpendicular to *a b* at *o*. The line *e f* is drawn parallel to the top face of the tool through the point *o*. The tool has an effective angle of top front rake

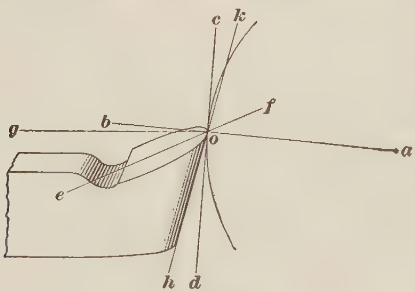


Fig. 6

b o e, which is larger than the tool angle *e o g*, and an effective clearance angle *d o h*.

Suppose that this same tool is lowered to the position shown in Fig. 7, the point of the tool being level with the axis of the work. By drawing the lines as before, the line *a b*

coincides with the horizontal line *o g*, so that the tool has less top front rake than before. The angle of clearance *d o h* is larger in Fig. 7 than in Fig. 6. The cutting action has

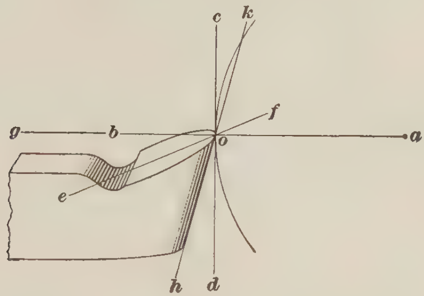


FIG. 7

changed from a shaving one in Fig. 6 to more of a scraping action, which makes it impossible to take so deep a cut.

Next, suppose that the tool is set far below the center, as shown in Fig. 8. By drawing the lines as before, *a b* passes into the tool below the line *e f*. In this position, the tool has a *negative* angle of top front rake *e o b*, and will do little more than scrape the work. The front clearance angle *d o h* is very large.

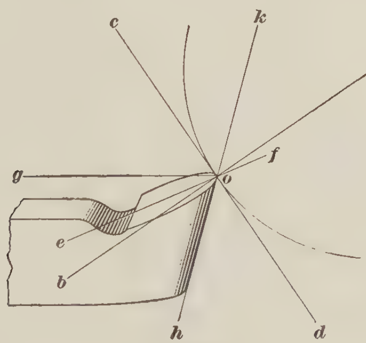


FIG. 8

9. Effect of Height of Tool on its Strength.—The effect of the position of a tool on its strength can also be seen from Figs. 6 to 8. In Fig. 6 the angle of clearance *d o h* is the

smallest, and the cutting edge *o* has the best support against the downward thrust of the work; consequently, the tool is in its strongest position. In Figs. 7 and 8 the angle of clearance *d o h* is greater, and the cutting edge has less support. Therefore, the tool is strongest when set as high as possible on the work.

10. Front Clearance Angle of Lathe Cutting Tools.—The larger the front clearance angle *d o h*, Fig. 6, of the tool, the greater will be the ease with which the tool can be fed straight into the work. On the other hand, if the clearance angle is made too large, the cutting edge may crumble because the angle of keenness *e o h* is decreased as the clearance angle *d o h* is increased, and the cutting edge receives less support. The clearance angles for lathe cutting tools in common use vary between 4° and 12°. A value that is often used is 6°.

11. Angle of Keenness.—The angle of keenness *e o h*, of the tool, Figs. 6 to 8, should be blunt enough to prevent the tool from crumbling at the cutting edge. The harder the metal to be cut, the more blunt must be the angle of keenness of the tool, as the intensity of pressure on the top or lip surface of the tool is much greater in cutting hard metals than in cutting soft metals, and the chip pressure is closer to the cutting edge. In cutting hard steels or chilled iron the angle of keenness should be nearly 90°. The cutting becomes almost entirely a crushing action, and the metal is broken off in small bits; or, with a wide-face tool, in long, slender slivers. Tools for cutting soft steel should be ground with sufficient keenness to enable them to turn long, curly, shavings; an angle of keenness of approximately 60° gives the best results.

12. Angles of Top and Side Rake.—Top front rake, angle *a*, Fig. 9, is given to a lathe tool because an absence of top rake tends to push the tool and the work apart, causing a variation in the size of the work and leaving an irregular finish. The angle of top rake depends on the weight of the cut; the heavier the cut the less the top-rake angle. When the tool is used for finishing, the cut is very light and most of the

cutting is done with the point or nose of the tool. In this case, a larger angle b of top front rake, of from 10° to 20°, depending on the kind of material, should be given clear to the end of the tool.

Side slope, or top side rake, c, as shown in Fig. 9, is given to a tool so that it may cut sidewise and take a deeper radial

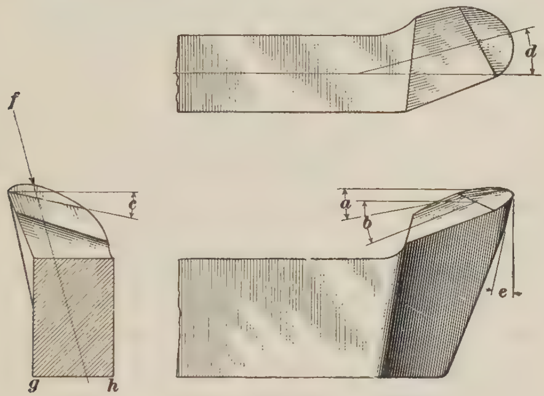


FIG. 9

cut. The top side rake also permits the tool to be ground many more times without weakening the body. Side rake also causes the chip to run off sidewise and prevents it from striking the tool post and becoming jammed; with side rake, less power is required to feed the tool.

13. Angle of Side Clearance.—The angle of side clearance depends upon the depth of the cut as compared with the rate of feed. Thus, when the cut is quite deep, and the feed is

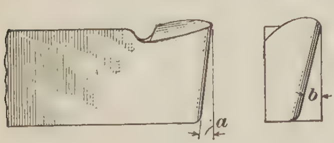


FIG. 10

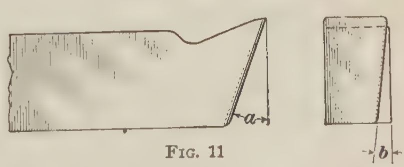


FIG. 11

light, giving a thin chip, the end clearance a, Fig. 10, should be small and the side clearance large. On the other hand, for a light finishing cut and a heavy feed, as in Fig. 11, the front

clearance *a* should be large, and the side clearance *b* quite small.

14. Leverage of Cutting Tool.—To insure stiffness the tool should be clamped in the tool post as close to the cutting edge as possible. If the cutting edge extends too far from the supporting block in the tool post the long leverage will result in a downward spring of the tool, which may cause the work to be spoiled. The point may dig in and cause injury both to the work and the tool.

SHAPE OF LATHE TOOL

15. Effect of Feed on Shape of Tool.—The shape and width of the point of a tool depend on the feed used, and this depends on the nature of the work. In finishing small rods, shafts, or spindles that should be very true, the roughing cut is made deep with as coarse feed as the work and the tool will stand; and the finishing cut is light, with the feed comparatively fine. The fine feed is allowable because it cuts the work very true, and on small work the tool will quickly feed over it and remain sharp up to the end of the cut.

On large work, the method is different. Deep, heavy roughing cuts are taken, as before; but the finishing cut is taken with a tool that has a broad, flat point and a very coarse feed. A broad-nosed tool should be used for finishing, whenever possible. It saves much time because of the coarse feed that can be used, and the tool will usually remain sharp until the end of the cut, unless the cut is very long.

16. Design of Lathe Cutting Tool.—As the dressing of a forged lathe cutting tool is much more expensive than the grinding, tools should be so designed that they may be ground the greatest number of times with a single dressing. The nose of the tool should be forged in such a way that the angles of clearance, top rake, and side rake will be greater than the corresponding angles of the tool when ground, in order that the least amount of metal will have to be removed by grinding.

The nose of the tool should be forged above the body of the tool, as shown in Fig. 9, in order that the tool may be reground

a large number of times before reforging becomes necessary. To avoid the tendency of a high tool to turn over sidewise when taking the cut, the nose is usually offset about 15° toward the cutting side of the tool, as shown at *d*, Fig. 9. The point clearance *e* may be 5°. The line of pressure *f* will then pass near the center of the base of the tool, or at least it will be within the base *g h*. In case the line *f* passes through the base support outside of the corner *h*, the cutting pressure acts to tip the tool over.

17. Shaping of Lathe Tool.—As the top surface of the tool receives much more injury than the front, or clearance, surface, a larger amount of metal must be removed at each grinding from the top surface than from the flanks. Usually the flank surface has to be ground on account of the wear caused by its rubbing against the work. The bottom, or heel, of the tool should extend forwards as far as possible so as to furnish a support under the cutting edge.

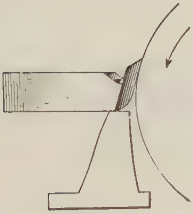


FIG. 12

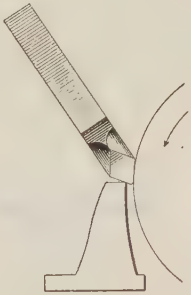


FIG. 13

Great care should be taken, in grinding lathe tools, not to overheat the cutting edge. Plenty of water should be used on the nose of the tool in grinding, as more tools are ruined by overheating in grinding than from any other cause.

18. Grinding Lathe Tools.—In grinding lathe tools held in the hand, the point should be finished by holding it up, when applied to the grindstone or emery wheel, as shown in Fig. 12. The water is thus allowed to strike the cutting edge

first, keeping it cool. The tool should never be held as shown in Fig. 13, in grinding by hand, as there is danger that it will catch between the wheel and the rest, and cause damage.

19. Change of Top Front Rake to Top Side Rake.—The angle of top rake may be changed from top front rake to top side rake by swinging the tool from its setting square with the work, and clamping it so that it cuts ahead of the tool post, thus changing the angle of the tool with the work. In Fig. 14 (*a*) is shown a broad-nosed finishing tool ground with top front rake and set square with the work. It may be changed to a very efficient roughing tool resembling a tool with top side rake, by swinging it so that it cuts ahead of the tool post in the position shown in (*b*).

20. Special care should be taken in using a tool set ahead of the tool post as in Fig. 14; for if it becomes loose in the tool post it will swing into the work and may do great damage. It is best to have the tool post in advance of the point at which the tool is cutting, so that the tool will swing away from the work if it becomes loose. This is not always possible; for example, in using right-hand bent tools for turning shoulders near the driving dog, it is necessary that the cutting point be

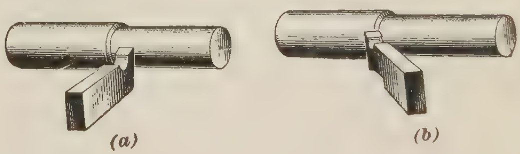
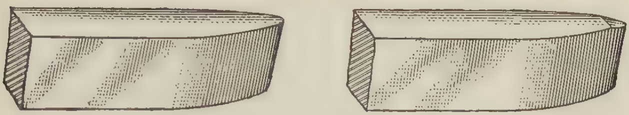


FIG. 14

set ahead of the tool post. In such cases the tool must be firmly clamped and the feed and depth of the cut so regulated that there is no danger that the tool will swing.

21. Shape and Setting of Tools for Brass Work.—In turning brass, the tool should have a blunt angle of keenness. This is necessary because of the softness and flexibility of brass. These qualities tend to cause a tool to spring into the work and the work to spring over the tool in such a way as to make

very untrue cuts. If the work and the tool could be held with sufficient stiffness to avoid all danger of springing, the tool could be ground with more keenness than is allowable for iron or steel. In practice, it is found that good results are obtained with a round-nosed tool ground without top rake or side rake,



(a) (b)

Fig. 15

as shown in Fig. 15 (*a*), and set with its top face level with the center of the work. Sometimes the tool is made with negative top rake, as in (*b*), the other angles remaining as in (*a*).

22. Tools for Turning Other Non-Ferrous Materials. For the softer grades of bronze the cutting tools should be ground without top rake or with negative top rake, as in the tools for cutting brass. The hard bronzes, whose copper content is high, require tools ground with top rake and in general, the harder the bronze to be cut, the less, or sharper, the angle of keenness that should be used.

Aluminum requires a keener tool than soft steel, preferably making a shearing cut.

Rubber for rolls etc., and compressed paper can be turned by the use of very keen tools.

23. Right- and Left-Hand Tools.—The tool, shown in Fig. 9, is called a right-hand tool for the reason that it is ground with top side rake to cut on the right-hand side or end of the work, and feeds from right to left toward the live center in the headstock. Most lathe turning tools are made in both right- and left-handed forms, with the exception of the cutting-off, or parting, tools, and the square-nosed finishing tools. A left-hand tool feeds from the left toward the dead center in the tailstock.

STEEL FOR LATHE TOOLS

24. Steels Used for Turning Tools.—The steels used for lathe tools are known as *carbon*, *high-speed*, and *semihigh-speed steels*.

25. Carbon Steel.—Carbon tool steel is steel that contains from .75 to 1.5 per cent. of carbon. It is more easily forged than either of the others and can be made of any desired degree of hardness. If, in forging, this steel is heated higher than a bright red, the carbon will be burned out and the steel ruined. In grinding or using, the cutting edge of the tool will be softened if heated to 550° F., as shown by the bluing of the steel. When the temper is drawn to a blue color, the edge will wear away rapidly and it will be necessary to harden and temper the tool again. This sensitiveness to heat limits the cutting speed of carbon-steel tools. Such tools can be run at a cutting speed of about 30 feet per minute, on cast iron or steel, and retain their sharpness unless the cut is very deep in proportion to the size of the tool, or the feed is excessive.

26. High-Speed Steel.—High-speed steel contains tungsten, or molybdenum and chromium, in addition to the iron and carbon, and a small quantity of vanadium. High-speed steel should be forged at a temperature of 1,800° or 1,900° F. The steel is usually heated and bent, and cut roughly to shape with a hot chisel. High-speed steel is harder to forge than either carbon or semihigh-speed steel. High-speed steel tools are less brittle and not likely to crack if annealed before using. Annealing removes the strains set up by the hammering and forging process. Therefore the tools are usually reheated to a forging heat, after they are dressed, and cooled on the floor. The tools are then rough-ground.

27. After being annealed, the tools are hardened by heating the entire nose slowly to a bright cherry-red heat, or about 1,500° F., then from this temperature up to a white heat, or about 2,200° F., as rapidly as practicable in an intensely hot fire. The tools are then cooled quickly to about 1,550° in a

blast of air, an oil bath, or a lead bath. From this temperature down to the temperature of the air, the cooling may be either fast or slow. The first part of the cooling, to about 1,200° F., should be continuous. The tool should not be allowed to have its temperature even slightly raised for a short time during this period, or it will be injured.

28. Red-Hardness of High-Speed Steel Tools.—High-speed steel tools properly heated will cut about four times the quantity of the same quality of metal in a given time as will carbon-steel tools. The great advantage of high-speed steel tools over all others lies in their property of red-hardness; that is, the tools remain hard, even after the nose of the tool has been heated red-hot through the pressure and friction of the chip. Because of this fact, much higher cutting speeds can be obtained by their use.

29. Uses of High-Speed Lathe Tools.—High-speed lathe tools may be used for all classes of work; but they find their greatest service in the rapid removal of stock from iron and steel forgings or castings, or bars which are turned down without first being forged approximately to the desired size and form. In cutting chilled iron, they can be made with so little top rake, that, if enough power is available, they do their work almost entirely by crushing, and yet retain their keen edge.

30. High-Speed Tools for Roughing and Finishing Cuts. With high-speed tools, shavings may often be cut from tool steel at such a high cutting speed that the heat generated will sometimes be sufficient to draw the temper color on the steel shaving to a dark blue. This is equivalent to a temperature of about 550° F. The best high-speed tools will work well even when the point of the tool is at a dark red. When used as finishing tools the cutting edges must be well oil-stoned and polished.

31. Design of Lathe for Use of High-Speed Tools. Lathes designed for the use of carbon-steel tools are not sufficiently powerful for the heavy cuts at the allowable speed that may be taken with high-speed tools, and they are not massive

enough to absorb the vibrations set up by the heavy cuts. The lathe that works to the best advantage must be built with large spindles and bearings and have plenty of driving power. It must also have its parts so designed that there will be metal enough used and correctly distributed to permit the tool to cut with the least vibration.

32. Semihigh-Speed Steel.—Semihigh-speed steels contain the same elements as high-speed steels; but the percentage of tungsten or of molybdenum and chromium used is not so high. In hardening, the tools are heated to a bright red and then laid down to cool in the air, cooled in an air blast, or quenched in oil. Those semihigh-speed steels that contain very little tungsten or molybdenum and chromium are sometimes cooled by quenching in water. Semihigh-speed-steel tools have greater endurance and work at higher speeds than carbon-steel tools; but they have less endurance and work at lower speeds than do high-speed-steel tools. They do not have the property of red-hardness to the same extent.

FORMS OF LATHE CUTTING TOOLS

ROUGHING AND FINISHING TOOLS

33. Straight Round-Nosed Tool.—The ordinary round-nosed tool shown in Fig. 16, with the point in the center, and

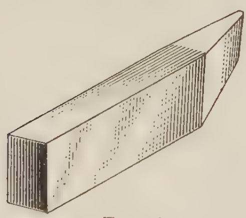


Fig. 16

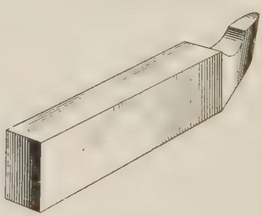


Fig. 17

ground straight on top, may be used to cut in either direction, for roughing or finishing operations. If top rake is to be given to the tool, the tool should be forged so that the top

rake can be ground easily. In Fig. 17 is shown how such a tool should be forged. This style of forging allows the top face of the tool to be ground, and the angles kept unchanged.

In Fig. 18 is shown a form of straight round-nosed tool used for some kinds of heavy work.

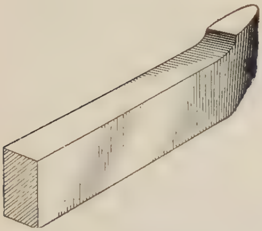


FIG. 18

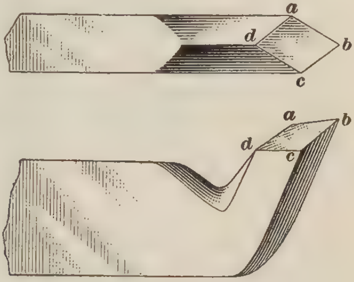


FIG. 19

34. Diamond-Pointed Tool.—The diamond point, or diamond-pointed tool, is shown in Fig. 19. The illustration shows a right-hand tool. Cutting is done by the left front edge *a b* and the point *b*.

35. Grinding of Diamond-Pointed Tool.—The diamond-pointed tool, Fig. 19, is sharpened by grinding the top face *a b c d* so that it slopes back from the point and down toward the right, to give the necessary keenness to the cutting edge *a b*. The two front faces *a b* and *b c* are then ground straight from point to heel by presenting the heel to the wheel first and allowing the grinding to continue upwards until the top face is reached. Starting to grind at the bottom insures taking more off at the bottom than at the top and gives plenty of clearance. After the top and the two front faces are ground, the corner between the two front faces is rounded slightly from the point to the heel to form a durable point that will cut a fairly smooth surface.

SIDE TOOLS

36. Form of Side Tool.—The side tool is a tool of the form shown in Fig. 20, and is used in squaring up the ends of work held between centers, or for forming shoulders. It may be

made either right-hand or left-hand, so that it can be used on either side of a piece. The form shown in the illustration is a right-hand side tool. The left-hand tool is offset in the opposite direction.

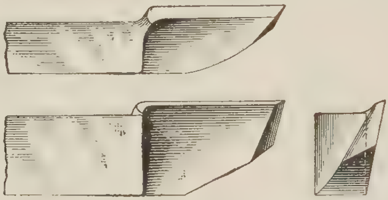


FIG. 20

In Fig. 21 is shown an end view of a correctly shaped side tool and illustrates how it is presented to the work as seen from the back of the lathe. The cutting edge of the tool is at the height of the center of the work, and the face *A B* of the tool is ground flat and at an angle to the line *C D*, which is parallel to the side of the shank. The small angle formed between the lines *A B* and *C D* is the angle of side clearance, usually about 12°. The top face denoted by the line *E F* is usually ground with an angle of 12° side rake.

37. In sharpening the tool the most grinding should be done on the top face *E F*, Fig. 21, care being taken to keep the original shape of the tool. In Fig. 22 is shown how a careless

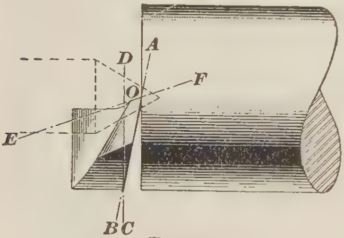


FIG. 21

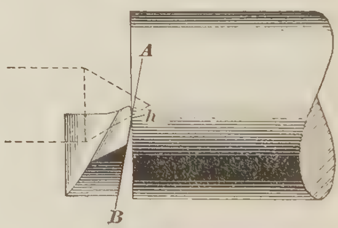


FIG. 22

workman may round the face *A B* of the tool in attempting to make the cuting edge sharp, with the result that the tool cannot cut because of the high place *h*, which touches the face of the work first. After a tool is ground on an emery

wheel or a grindstone, it should be finished on an oilstone, to give it a keen edge, for finishing cuts.

38. Operation of Side Tool.—The side tool, when facing the ends of work, should always operate from the center out toward the rim of the work, and the tool should be set so that not the point but the edge does the cutting. The side tool is sometimes used as a forming tool by setting the cutting edge to the angle of the surface of the work, as the end of a small shaft to be squared up, or an edge or face of a bevel gear, and making the whole cut at one setting.

PARTING, OR CUTTING-OFF, TOOL

39. A common form of parting tool is shown in Fig. 23. It is used for cutting square grooves or notches in work, for cutting square corners, and for cutting off work. The cutting

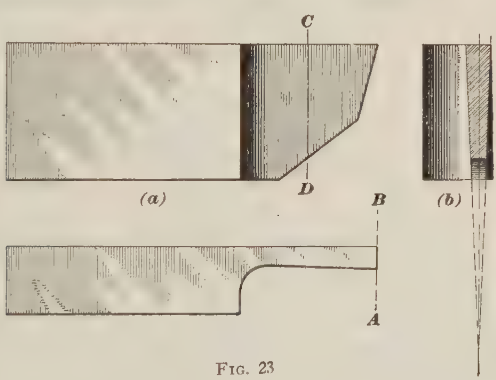


FIG. 23

edge of the tool is along the top front line AB. The blade is forged and ground so that the cutting edge is the thickest part. Each side of the blade is ground with a slight amouut of clearance, as shown by the section CD, to prevent the tool from binding in the groove. The tool is not ground with top rake, keenness being given by varying the angle of front clearance. When this tool is used for cutting off, it should be set at the same height as the center of the work, and square with the axis.

BORING TOOLS

40. Boring Operations on Lathe.—The operation of turning and enlarging cylindrical or conical holes is known as *boring*. The operation is performed by causing the work to turn on its axis while held in a chuck or bolted to a face plate, the tool being fixed in the lathe carriage; or by fixing the work securely to the carriage, while the tool revolves upon a bar placed between the lathe centers. In Fig. 24 is shown a forged boring tool to be held in the tool post of the lathe. As it is impossible to support this type of tool so that it is perfectly

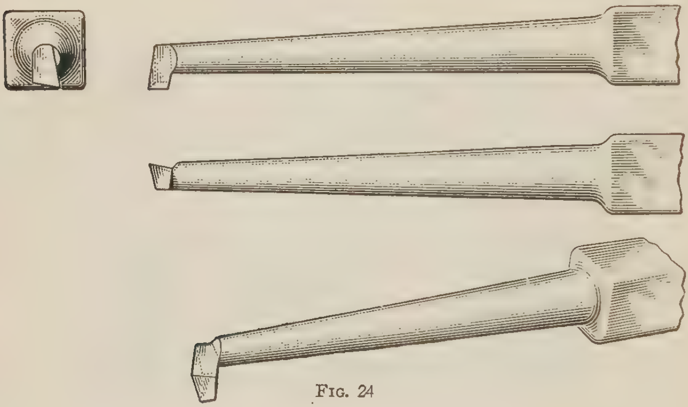


Fig. 24

rigid, or without some spring, the hole made by such a tool cannot be absolutely true and of exact size. There is always a little spring to a tool supported at one end, and generally to the work itself, so that in quantity work where bored holes are to be duplicated many times, a reamer is usually used after the boring operation, to finish the hole to the exact diameter.

41. Whether the hole produced by the boring tool will be true and concentric with the outside of the work depends on the shape of the hole in its rough state. Usually, cored holes, which are those molded in the castings, will run out of true when the work is set up in the machine and it is well to start with a stiff boring tool, or in small holes a flat drill or a three-lip drill may be used to finish.

42. Shape of Boring Tools.—Boring tools for roughing cuts are ground round on the point, similar to the round-nosed

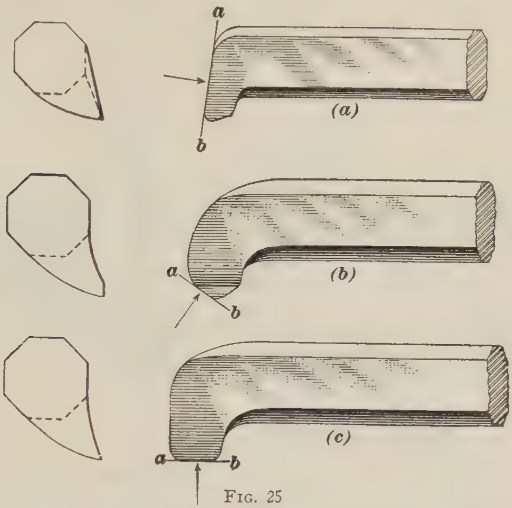


Fig. 25

turning tool, with front and side clearance, and plenty of top side rake. Roughing cuts are generally made deep, with a moderately fine feed. The finishing cuts are made with as coarse a feed as the tool will stand. The finishing tool, therefore, has a broad cutting edge with a minimum of clearance. In Fig. 25 (*a*) is shown a well-shaped tool for small work. The point is narrow, and has much the same shape as that of a diamond point. The force tending to spring the tool away from the work is in the direction of the arrow, at right angles to the line *a b*. In (*b*) is shown a tool with the point more

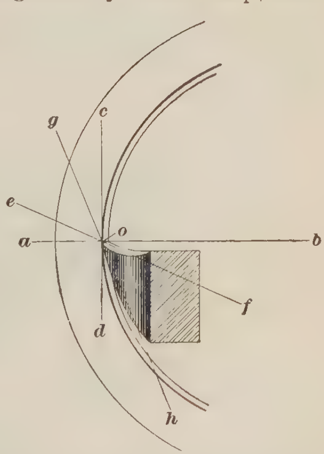


Fig. 26

rounded, with the force tending to spring it away from the work more nearly at right angles to the shank of the tool. In (*c*) is

shown a broad-nosed tool with the force acting squarely across its shank. This tool may chatter and spring away from the work. Single-pointed boring tools should have narrow points, as shown in (*a*), and should be used with moderately

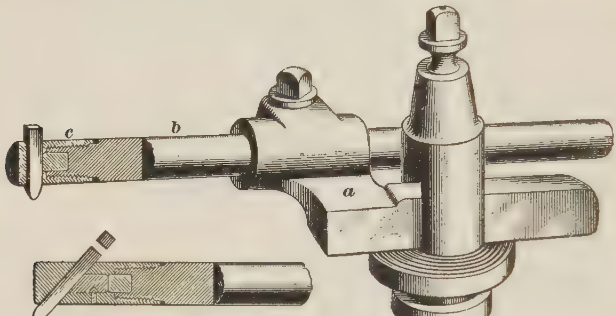


Fig. 27

fine feeds. Broad-edged boring tools used with coarse feeds are held in boring bars or heads. The cutting edge of a boring tool is not so strongly supported as in other lathe tools because of the long, slim arm required to reach to the bottom of the holes.

43. Cutting Angles for Boring Tools.—As shown in Fig. 26, the angles of rake and keenness for a boring tool may be defined the same as in a turning tool. The line *a b* is drawn from the

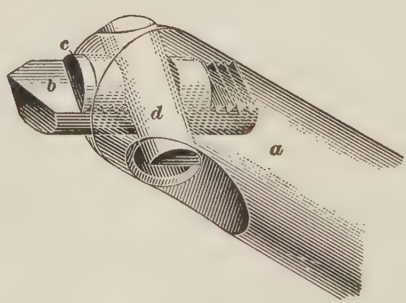


Fig. 28

center *b* of the work through the point of the tool, and *e f* is drawn along the top face of the tool through the point *o*. The angle *b o f* represents the angle of top rake. If the

tool is raised or lowered in the hole, the effective angle of top rake will vary. The angle of clearance is *d o h*.

44. Holders for Boring Tools.—For boring tools, special holders with inserted blades are superior to forged tools. In

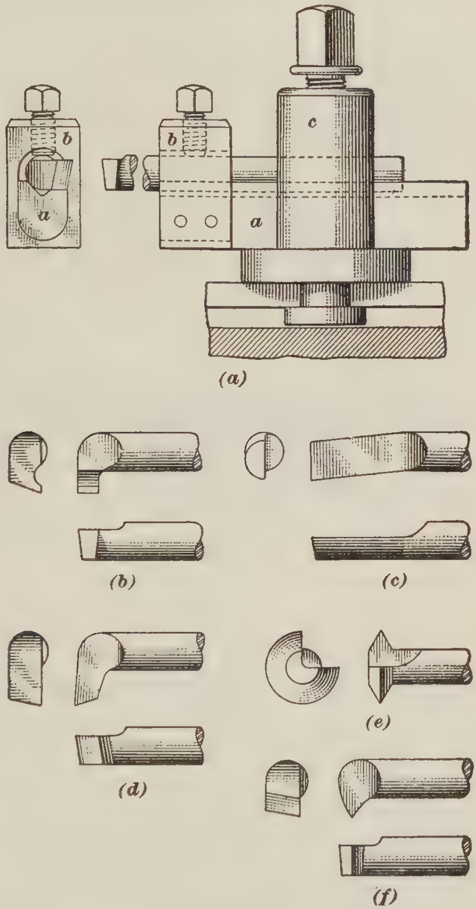


Fig. 29

Fig. 27 is shown a boring-tool holder *a* with the blade held in the end of the bar *b* by a cap *c*, which screws over the end of the bar. The bar *b* can be adjusted in the holder so that it will just pass through the work. In Fig. 28 is shown a boring-

tool holder that has no protruding setscrew head to obstruct the chip room needed in the holes. The bar *a* clamps in the tool post, and the cutter *b* is locked in the holder by means of the key *c* and tapered wedge *d*. The threads of the key mesh with the threads on the cutter, and the key is held in place by adjusting the tapered wedge in the groove cut in the key.

45. Tool-Set Boring-Tool Holder.—A boring-tool holder for a set of tools is shown in Fig. 29 (*a*). The shank *a* has a **V** cut in the top to take a boring tool made from round stock of any required length. A clamp *b* on the working end of the holder adds stiffness to the tool when it has been adjusted to the required length to bore to the necessary depth. The tool and holder are clamped rigidly in the tool post *c*. A recessing tool is shown in (*b*), a straight-nosed tool in (*c*), a common boring tool in (*d*), a circular internal threading tool in (*e*), and an internal threading tool in (*f*).

TYPES OF BORING BARS

46. Definition of Boring Bar.—When the work is heavy or the holes comparatively long, boring can be done by clamping the work to the carriage, and revolving the tool in a bar held

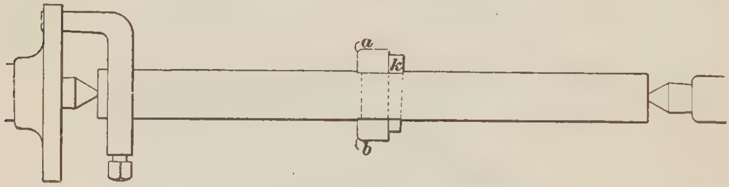


FIG. 30

between the lathe centers. This bar is called a boring bar. The cutters that do the boring are held in slots in the bar, or in facing heads clamped to the bar.

47. Boring Bars With Fixed Cutters.—A common type of boring bar, Fig. 30, has a fixed cutter in the middle that may cut only on one end, or both ends will cut if they project equally. The cutter is fitted in a rectangular slot and is held in place by a key *k* driven in at the back. The cutter blade

should be turned to the desired diameter before it is hardened. The cutting is done by the points or edges *a* and *b*. When this style of bar is used, it must be twice as long as the hole to be bored, as there must be room for the work at one side of the cutter before it is started, and room for it to pass beyond the cutter after the cut is finished.

48. Boring Bars With Cutter Heads.—When the hole in the work is large, so that the cutter will project a considerable

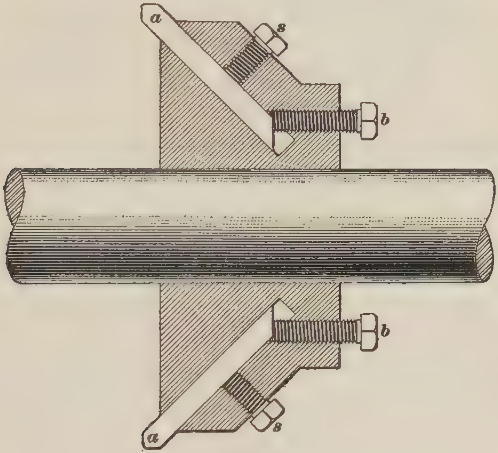


FIG. 31

distance beyond the bar, it is best to fix a cutter head to the bar. Such a head is shown in Fig. 31. It consists of a cast-iron collar carefully fitted to the bar and kept from turning by a key and a setscrew. Four cutters *a* are generally inserted in the head and held in place by the setscrews *s*. The setscrews *b* are used to adjust the cutters. It will be seen that by tightening the screws which rest against the ends of the cutters, the latter will be pushed out of their sockets. As the cutter becomes short, a filler block must be put between it and the screw to make the latter effective.

For boring holes of large diameter, a cast iron disk *a*, Fig. 32, keyed to the bar and holding an adjustable single cutter *b*, may be used. The cutter may project straight from the disk,

as at *b*, or at an angle, as at *c*, so that sharp corners in a cylinder or other work, may be finished.

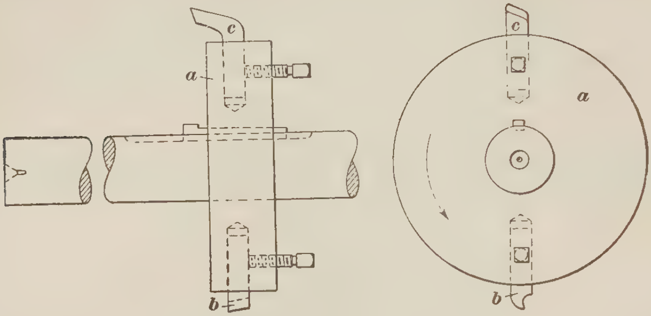


Fig. 32

49. Boring Bar With Traveling Head.—For boring heavy work, the traveling-head or traverse-head, type of boring bar, shown in Fig. 33, is desirable, as the work is not moved along the bar. The bar *a* is fitted with a head *b* that slides on the bar. The head is kept from rotating on the bar by a key that slides in a keyway cut the entire length of the bar. Four cutting tools *c* are used, and are held in place by setscrews *d*. Clamps or wedges are often used to hold the tools in the head. A feed-screw *e*, supported in bearings at either end of the bar,

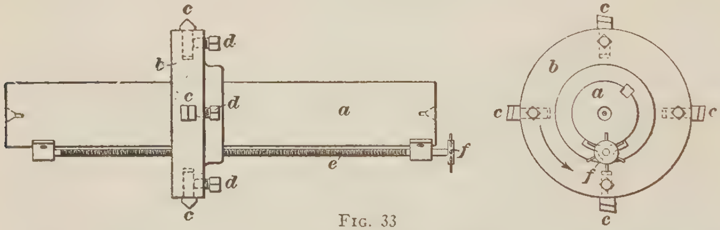


Fig. 33

passes through a nut in the sliding head. By revolving the feed-screw, the head is moved along the bar. The feed-screw is generally set in a slot cut in the side of the bar to protect it from injury and dirt. A star wheel *f* on the end of the feed-screw is tripped by a stud secured to some part of the machine and rotates the feed-screw a part of a turn each time the bar revolves.

TOOL HOLDERS FOR TURNING TOOLS

50. Advantages and Disadvantages.—The expense of keeping up a stock of tools forged from the bar, whether of carbon steel or of alloy steel, is great, and this fact has led to the devising of many forms of holders employing small blades of steel to do the cutting. Holders are made of the same size

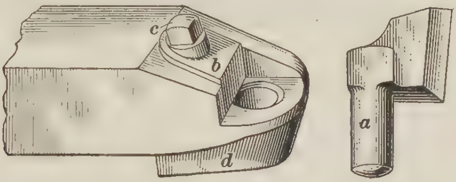


Fig. 34

as the shank of the ordinary forged tool. They make a very great saving in the cost of the alloy steel used, as one holder will be sufficient for a great variety of shapes of cutting points, tools, or blades. The blades may be of the very finest and most expensive quality of high-speed steel, and still the complete tool will cost far less than the forged tool.

The objection to inserted-blade tools or tool holders is that it is difficult to find a means of clamping the small blade in the holder so that it will have the same rigidity as the forged tool. The holders soon wear, allowing the blades to spring. In many cases this is caused by using too small a holder. If heavy holders and comparatively large blades are used, the trouble will be partly avoided.

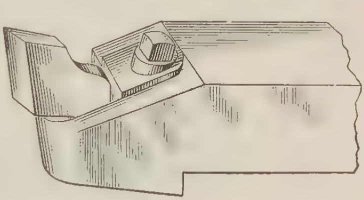


Fig. 35

51. In Fig. 34 is shown a tool holder that serves for a variety of cutters. The shank of the cutter *a* is inserted in the holder in a vertical position and the cutter is locked by the clamp *b* held by the setscrew *c*. The extension *d* at the end of the holder acts as a support for the heel of the cutter. In Fig. 35 is shown an assembled tool.

A similar type of tool holder, shown in Fig. 36, is flattened out in front to admit the horizontal shank *a* of the side cutter *b*. The tool is held in place by a clamp and setscrew at the back of the holder.

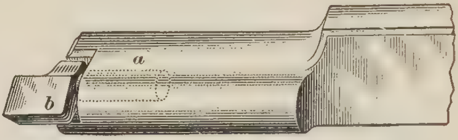


Fig. 36

52. Grinding Inserted Cutters.—Cutters that are inserted in holders are ground by hand, or in a machine, by fastening them in a special holding device, such as is shown in Fig. 37.

53. Inserted-Blade Parting Tool.—Inserted-blade tool holders are very successfully used for parting tools. In Fig. 38

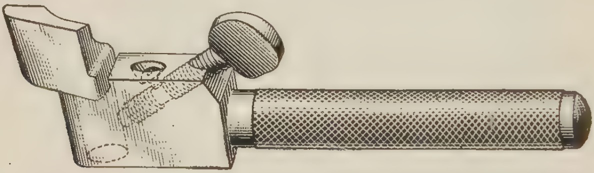


Fig. 37

is shown one style of inserted-blade parting tool. The blade is held in the holder by the clamping screw *s*, and is still further secured, when the tool holder is clamped in the tool post, because of the spring of the tool holder. In Fig. 39 is shown an offset form of parting tool with inserted blade. The

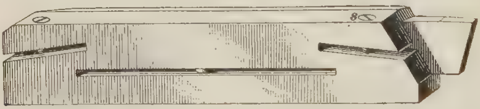


Fig. 38

blades for these tools are ground either concave on the side or thinner on the bottom edge, to give clearance.

54. Heavy Inserted-Blade Tool Holder.—The tool holder and tool shown in Fig. 40 are designed for heavy cuts and high

speed. The form and angles of the cutter are the same as those of a forged roughing tool. The cutter *a* is to be ground only on the top face, and can be used until very short. The objection advanced against tool holders in general for heavy work is

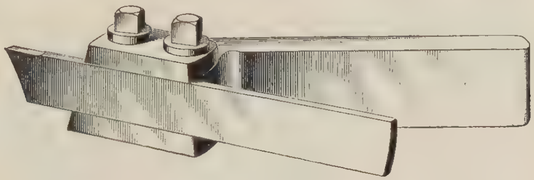


Fig. 39

that, because of lack of proper contact of the tool with the holder, they do not carry off the heat generated by the chip. The holder shown in Fig. 40 is designed to overcome that trouble by making both the cutter *a* and its key *b* have a large contact with the holder. The cutter *a* and the key *b* may be

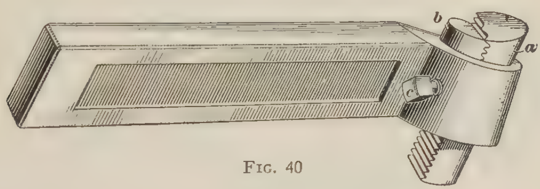


Fig. 40

raised or lowered together or each may be adjusted for height separately. The locking screw *c* holds both the cutter and the key.

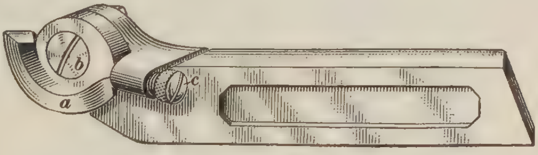


Fig. 41

55. Inserted-Blade Thread-Cutting Tool.—Inserted-blade threading tools are illustrated in Figs. 41 and 42. The cutter *a*, Fig. 41, is held in the holder by the screw *b* and can be made to swivel around the smooth part of the screw. In this way

slight adjustments of height can be made. It is locked in position by the screw c.

In Fig. 42 the cutter a may be raised or lowered by the screw b that engages a rack c at the back of the cutter. The

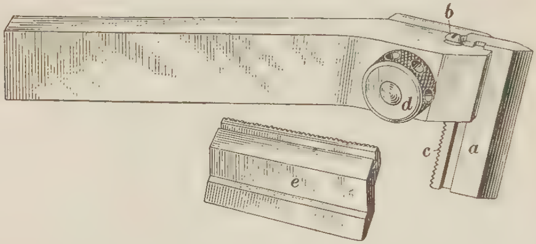


Fig. 42

cutter is gripped in the holder by the heavy nut d having holes in its circumference to receive a pin wrench. Grinding is done on the top end of the cutter only. An offset cutter is shown at e. An inside-threading cutter a, mounted in its holder, is shown in Fig. 43.

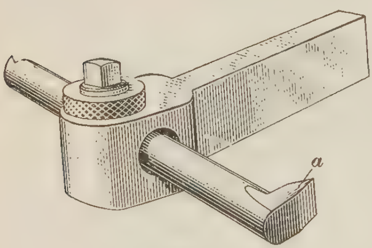


Fig. 43

56. Knurling Tool. Knurling is done either to provide a rough surface that can be firmly gripped by the hand or to produce an ornamental effect. Handles of gauges, and the thumb screws used on instruments are usually knurled. A knurling tool for use in the tool post of a lathe is shown in Fig.

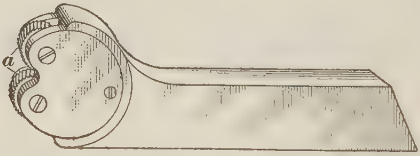


Fig. 44

44. The knurling is done by two hardened wheels, or knurls a, having spiral teeth cut in opposite directions. The tool is forced slowly into the work as it revolves in the lathe. One

knurl forms a series of left-hand ridges, and the other, right-hand ridges, which cross and form diamond-shaped impressions. Plenty of oil should be used during the operation. Usually the work must revolve several times before the projections

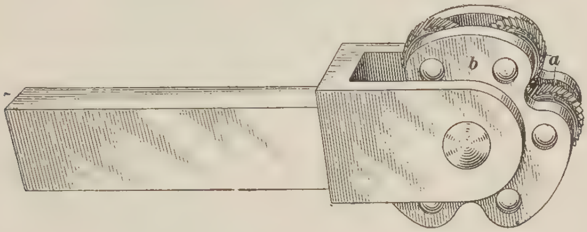


FIG. 45

are well formed. In Fig. 45 is shown a knurling tool having three pairs *a* of knurls, coarse, medium, and fine, mounted in a revolving holder *b*.

BENT TOOLS

57. For some kinds of work, the straight tools that have been described cannot be used, and a class of tools known as bent tools becomes necessary. They are classed as right-hand or as left-hand bent tools, depending on the direction in which they are intended to cut.

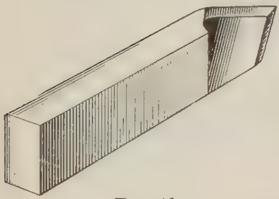


FIG. 46

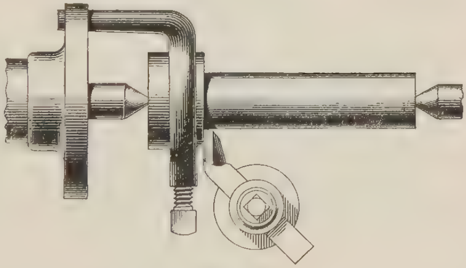


FIG. 47

58. A right-hand bent side tool is shown in Fig. 46. This form of tool is especially desirable when cutting a shoulder that is very close to the lathe dog, as shown in Fig. 47.

59. Round-nosed tools may be bent either right or left, to meet certain conditions of work. The right-hand bent

round-nosed tool is often used for facing, and it makes a good inside turning or boring tool, in large holes. A forged left-

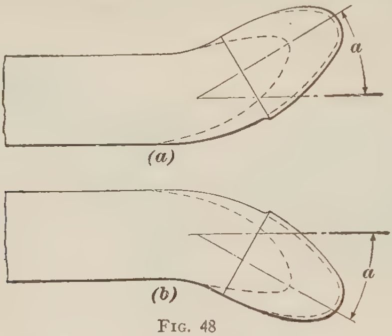


FIG. 48

hand bent round-nosed tool is illustrated in Fig. 48 (*a*) and a right-hand tool in (*b*). The angle *a* is 30°.

FORMING TOOLS

60. Advantages of Forming Tools.—When surfaces are to be finished with a curved or an irregular outline, the turning can be done better and quicker by the use of forming tools. These tools are usually fed at right angles to the work axis, and hence do not require complicated feed motions and great skill from the operator. Furthermore, the work can be tested usually by measuring but one diameter of the section. The lathe should have plenty of power, and the work and tool should

FIG. 49

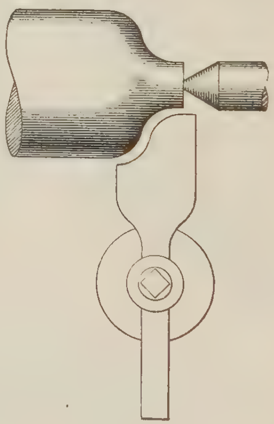


FIG. 50

be specially rigid. The two classes of forming tools are known as the *flat*, or *straight*, and the *circular*.

61. Flat, or Straight, Forming Tools.—An example of a flat forming tool is shown in Fig. 49 and its application to the work in Fig. 50. Considerable front clearance *a b* is required. Where no side clearance is given on any of the surfaces, the tool can be sharpened by grinding on the top face without changing its true forming outline. Even when side clearance is filed or ground in the angular shapes, the error in most cases from regrinding is too slight to be regarded.

The flat forming tool shown in Fig. 51 is used to turn the tire threads on locomotive drive wheels. A high-speed steel cutter *a* is clamped by screws to a carbon-steel shank *b*. The top front rake on these tire tools is usually from 6° to 12°, and the front clearance angle from 5° to 8°

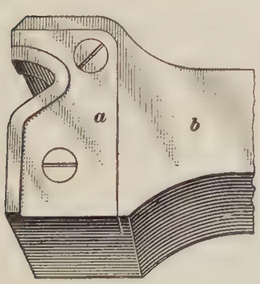


Fig. 51

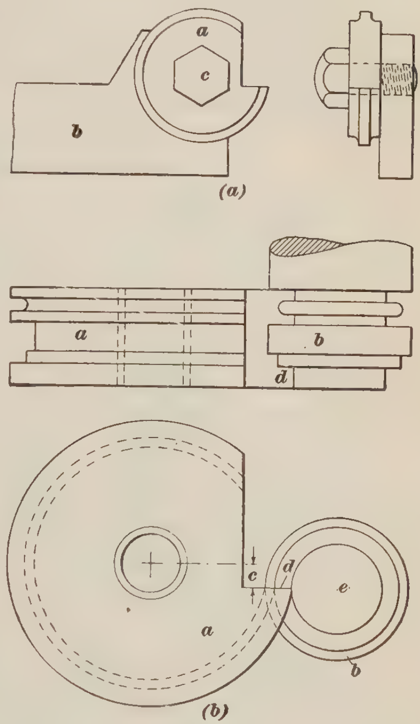


Fig. 52

62. Circular Forming Tools.—Circular forming tools may be ground repeatedly without changing their shape. Their clearance is given by locating the cutting edge below the center of the cutter, and not by the filing or grinding. On the other hand, the cutting edge of the circular tool is not so

well supported as that of the straight tool; for this reason the straight tool is better for heavy cuts.

In Fig. 52 (*a*) is illustrated a double corner-rounding circular forming tool. The cutter *a* consists of a tool-steel disk with its edge turned right and left to an arc of a circle to produce convex rounded corners on the work. The cutter is securely clamped to a holder *b* by a capscrew *c*.

An example of a circular forming cutter *a* with the work *b* is shown in Fig. 52 (*b*). The clearance is given by making the notch in the edge of the cutter about $\frac{1}{8}$ of an inch below the center, as shown at *c*. The cutting surface *d* should be set on a level with the center *e* of the work.

SPRING AND DROP TOOLS

63. Spring Tools.—In most cases, rigidity of work and tool is sought for the purpose of producing the smoothest and the most accurate surfaces. In some cases spring tools are

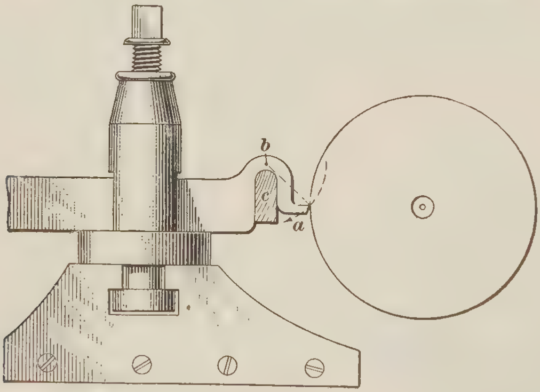


FIG. 53

used to overcome chattering or some roughness of cut that cannot otherwise be avoided.

64. In Fig. 53 is shown a *spring tool*, or *gooseneck tool*, as applied to the work. It should be set with its cutting edge level with the center of the work; then the pressure of the cut tends to press the edge away from the work in a circle *a*

drawn about the center *b*, at the top of the bend, and prevents any digging in. The groove under the neck is sometimes fitted with a piece of soft wood *c* tightly driven in. The tendency of the tool or the work to vibrate or chatter is taken up by the narrow, or springy, part *b* of the tool, and the wood *c*.

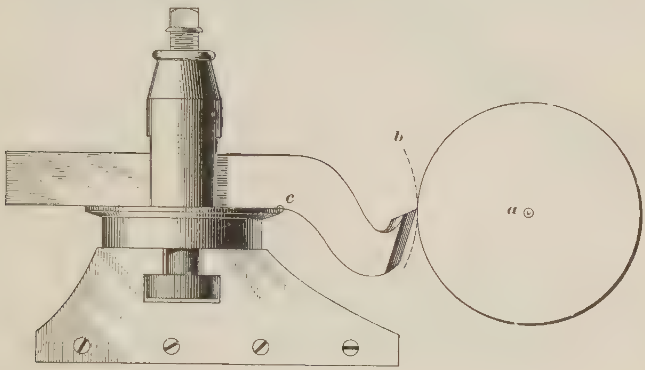


FIG 54

65. Drop Tools.—A drop tool, as shown in Fig. 54, is used where the holding device would set the edge of an ordinary tool too high to cut properly. The cutting edge of the drop tool should not be set higher than the center of the work *a*, otherwise the pressure of the cut would tend to draw the edge into the work. Thus, as any downward spring of the tool will swing the cutting point in a circle *b* about the edge of the support *c*, the cutting edge should not be above the point *c*.

LATHE HAND TOOLS

66. General Description.—Hand tools, or *gravers*, as their name implies, are held in the hand while operating on the work. Their cutting action depends on the skill of the workman. Their cutting power, compared with tools held in a slide rest, is very small. Their principal use in metal working is the turning and finishing of a great variety of work on hand lathes or small bench lathes for working brass, and for finishing curves and pieces of irregular outline.

67. Hand tools are commonly made from worn-out files of either square or rectangular section. Their points can be ground to any particular shape best suiting the work. They are also made from flat files ground to any required curve, either right-hand or left-hand, and are used for finishing turned cast-iron surfaces in the lathe preparatory to polishing.

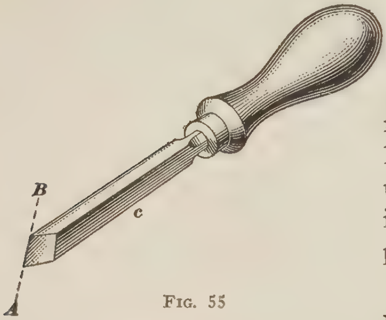


Fig. 55

68. Diamond-Pointed Hand Tool.—The diamond-pointed hand tool is a piece of square steel ground with a bevel on the point, as shown in Fig. 55. When this tool is used for rounding a corner, such as the end of a bolt or screw, it rests

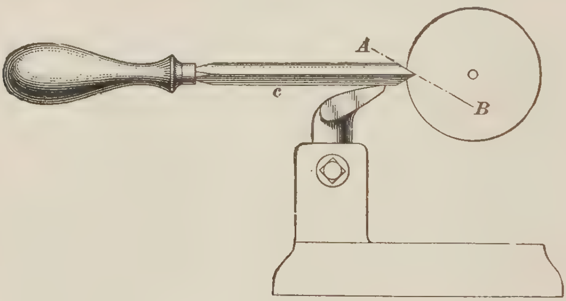


Fig. 56

on one edge *c*, Fig. 56, while the keen edge *A B* does the cutting. The angles of rake and clearance are easily changed to give the best results by changing the position of the tool

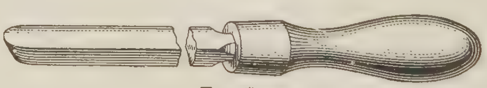


Fig. 57

69. Round-Nosed Hand Tool.—The round-nosed tool shown in Fig. 57 is used for finishing concave curves. The under side lies flat on the rest when it is used.

70. Three-Cornered Hand Tool.—The three-cornered tool shown in Fig. 58 is made from a three-cornered file from which all of the teeth have been ground on a wet wheel. The

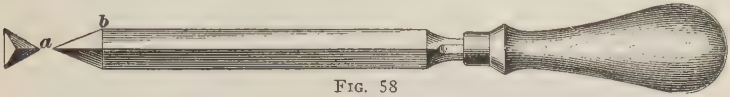


FIG. 58

end is ground to a sharp point, which gives three sharp cutting edges, as *a b*. This tool is very largely used to scrape center holes and to remove burrs from the ends of plain holes.

CHUCKING TOOLS

71. Method of Holding Chucking Tools.—When the holes are small, or not over 3 inches in diameter, they can be rapidly and accurately bored in work held in the lathe chuck by using tools called chucking tools. These tools may be

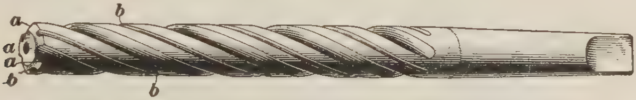


FIG. 59

held in a special holder on the carriage, or in the tailstock in place of the dead center. The latter method is the more common. When a chucking tool is to be held in the tailstock spindle, care should be taken to see that it is perfectly in line with a live spindle; otherwise, the hole will be spoiled.

72. Boring With Chucking Drills.—For boring cored holes, drills with three or four cutting edges are used. Chucking

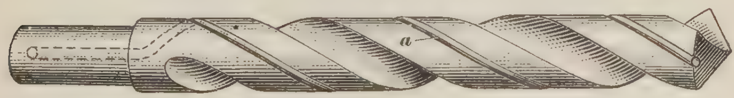


FIG. 60

drills are made with either straight or taper shanks, as shown in Figs. 59 and 60. The style in Fig. 59 can be held on centers, and the lands between the three cutting edges *a* have oil

grooves *b*. A small circular oil tube *a* in each land, Fig. 60, connects through the socket with an oil reservoir.

73. Flat Drills and Holders.—For rough boring in cored holes, the flat drill shown in Fig. 61 is sometimes used. It may be made from flat bar steel with the point ground like the

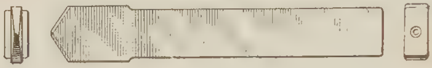


FIG. 61

point of an ordinary flat drill. The other end has a large center hole for receiving the dead center.

74. Flat Drill With Wooden Faces.—To finish the hole more perfectly than the flat drill shown in Fig. 61, the drill, shown in Fig. 62, may be used. This drill is made of flat bar steel, and turned parallel on the sides *c* and *d*, (*a*), to a diameter equal to the diameter of the desired hole. The cutting edges are the beveled edges *a* and *b*. This drill is

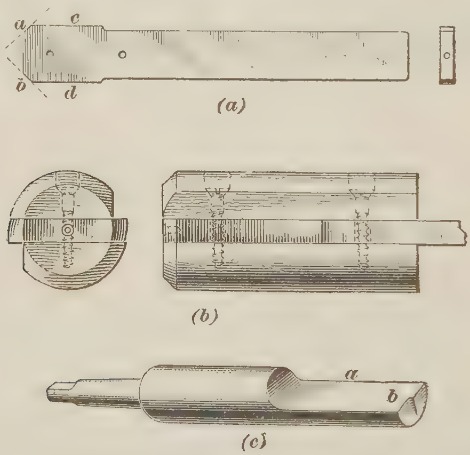


FIG. 62

covered with wooden faces to keep it from chattering and to guide it so that the holes will be more nearly accurate.

The wooden faces are made of two blocks of hard wood clamped on by wood screws, as shown in (*b*). After the blocks

are clamped in place they are turned or ground to the size of the drill, and the wood is cut away above the cutting edges to give room for the chips to work out. The wood should be well oiled before turning it to size in order that it will not swell to over size when in use.

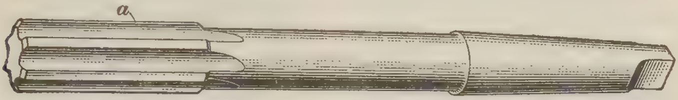


FIG. 63

75. Cannon Drills.—A cannon, or hog nose, drill is shown in Fig. 62 (*c*). Half of the stock of the drill is cut away, as shown at *a*, and the cutting edge *b* is at the end. A guide hole is necessary for starting this drill, but when once started true it drills straight. The drill is used for extra long holes and for squaring the bottom of the holes already drilled with a pointed drill.

76. Rose Chucking Reamers.—A reamer for following the flat drill, or for taking out considerable stock, is known as a *rose reamer*, one form of which is shown in Fig. 63. The body *a* is ground straight. It cuts on the end only.

77. Fluted Chucking Reamers.—In Fig. 64 is shown a fluted chucking reamer for finishing long holes smooth and true to standard size. It has more cutting edges than the rose chucking reamer, Fig. 63, and they extend the whole length

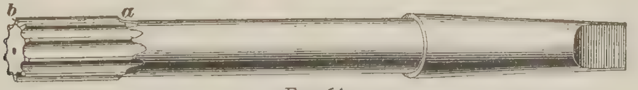


FIG. 64

of the flutes *a b*. The rose reamer should leave about .005 inch of diameter for the fluted reamer to remove in finishing. As it is intended for finishing holes to exact diameter, it should be used with considerable care; hence, the cutting speed is reduced, and the feed is increased.

78. Shell Chucking Reamers.—In Fig. 65 (*a*) is shown a shell chucking reamer of the rose-reamer type, which cuts on

the end only; and in (*b*) is shown a finishing shell reamer of the fluted type, which cuts along its full length. These reamers are, in many cases, more convenient than the reamers just described that are solid with the arbor. A shell reamer is

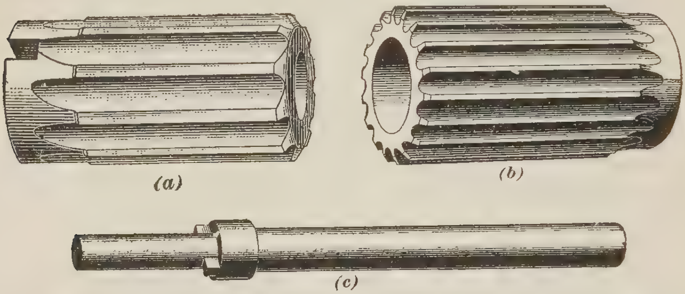


Fig. 65

simply the cutting part of a reamer made hollow, and used on a shank of any required length. It is cut the same as the regular reamer, and is cheaper, as less tool steel is required to make it. One arbor (*c*) can be used for several sizes of shell reamers.

79. Adjustable Shell Reamer.—An adjustable right-hand shell reamer is shown in Fig. 66. The high-speed steel

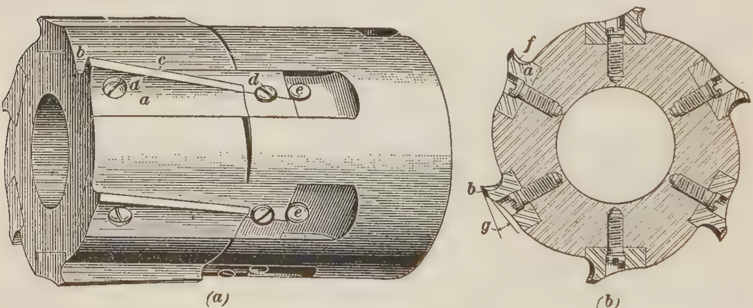


Fig. 66

blades *a* that cut both on the ends *b*, and along the edges *c* are fastened with two screws *d* in straight grooves in the shell. Plugs *e* are used to take the end thrust of the blades. The helical form of the cutting edges is cut on the milling machine.

Adjustment for wear is made by putting thin tinfoil or hard paper under the blades. The curved blades are an advantage when the reaming is heavy, especially in soft steel that may have a tendency to tear; also, this type will carry the chips from the hole. The straight blades are best for cast iron and short holes. The cutting edges are made hooked, as at *f*, and with plenty of clearance *g*, for the best cutting in steel. The cutting speed should be about one-half to one-third or less of the turning speed, with a feed anywhere from $\frac{1}{24}$ inch to $\frac{1}{4}$ inch. A flood of lard oil makes the best lubricant.

80. Chucking Reamer With Single Two-Edge Cutter.—A chucking tool for either regular or odd sizes of work is shown in Fig. 67. Its taper shank is held in the tailstock spindle.

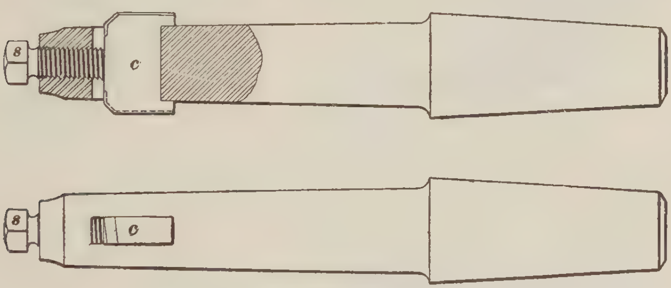


FIG. 67

The blade or cutter *c* is held in the bar by a setscrew *s*. Cutters of different sizes may be made at little expense to take the place in many instances of the more expensive standard chucking tools.

81. Interchangeable Pilot Bushing for Boring Bars.—In Fig. 68 is shown an interchangeable pilot bushing for supporting the end of a boring bar. This bushing consists of an outside or master bushing *a* of cast iron, that is ground to fit the bore of the lathe chuck, and an inside or pilot cast-iron bushing *b*, which may be changed to suit the size of the end of the boring bar. It is ground to a sliding fit on the boring-bar pilot and remains stationary with the boring bar, while the master bushing *a* revolves around it. An oil chamber *c* in the master *a*

surrounds the bushing *b* and keeps the surfaces of the two bushings lubricated. A felt plug *d* through the pilot bushing *b* supplies some oil to the inner surface in contact with the revolving boring bar. Two retaining washers *e* keep the pilot bushing *b* in place, and a wiper washer *f* between them aids in

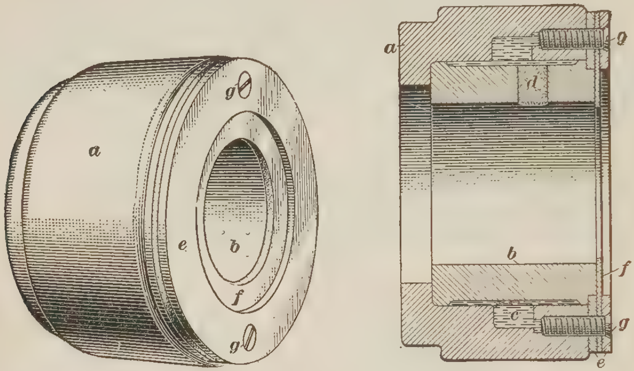


FIG. 68

keeping the oil on the bar. The two screws *g* extend into the oil chamber *c* as shown, and the chamber may be refilled through either of these screw holes.

DIAMOND-SET LATHE TOOLS

82. Diamonds Used in Lathe Tools.—Diamonds for industrial use have the same hardness as the gem diamonds, but lack their brilliancy. Industrial diamonds are found in two different forms, bort and carbon.

83. Bort.—Bort is the trade name for diamonds that are unsuitable for use as gems on account of their color, structure, small size, etc. They are chiefly mined in South Africa, and are used for dressing or truing grinding wheels, and for light turning operations.

84. Carbon.—Carbon is the trade name for the *black diamonds* found in Brazil. They are used to turn hard rubber, fiber, celluloid, mica, bakelite, glass, quartz, and so forth.

These materials, because of their abrasive action would soon dull the cutting edge of steel lathe tools. Diamond-set tools are sometimes used to cut fine threads on tough bronzes.

85. Mounting of Diamonds in Tools.—Diamonds are usually cast right in the solid steel of the tool shank. In casting, the steel goes into every crevice and irregularity of the stone, and in cooling, the shrinkage of the steel still further increases the tightness of the mounting. In Fig. 69 a round pointed cast-steel shank is shown. Only the smallest point of the diamond *a* protrudes. As the diamond wears, the surrounding metal must be ground away to expose a new cutting edge of the stone. Usually the diamonds are set in $\frac{1}{4}$-inch square steel shanks, or $\frac{3}{8}$-inch round steel shanks, about 4 inches long. The steel shanks shown in Figs. 70 and 71 are

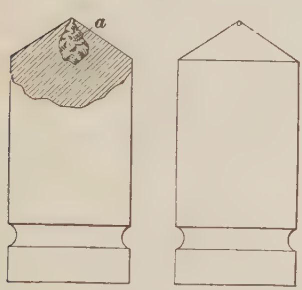


Fig. 69

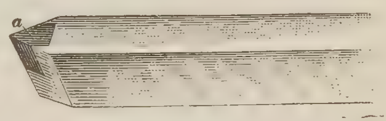


Fig. 70

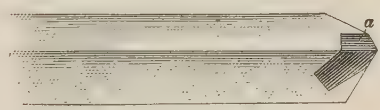


Fig. 71

set with shaped carbon points *a* ground to a fine cutting edge. In Fig. 70 is shown a **V**-pointed threading tool, and in Fig. 71 a left-hand turning tool.

86. Care of Diamond Tools.—A diamond set tool is well able to stand up under a steady pressure, but is liable to chip from a blow or shock, as the hardness of the stone makes it very brittle. The work should therefore be well supported and the cutting tool should not be allowed to chatter. When the tool is held in the tool post it should never be struck with a hammer in order to move it into a correct cutting position, as such blows may cause cracks in the stone. One of the prin-

cipal causes of trouble is overheating the diamond. This is done by taking too heavy a cut or using too fast a feed, by using the diamond after it is worn down to a flat surface that rubs rather than cuts, or by using insufficient water for cooling in

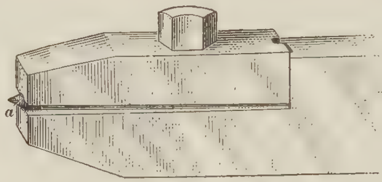


Fig. 72

grinding or cutting. The overheating will expand the diamond and loosen the setting. A loose stone vibrates and eventually cracks.

To preserve a diamond cutting tool it is best, therefore, to take light cuts, never to heat up the diamond, and when the

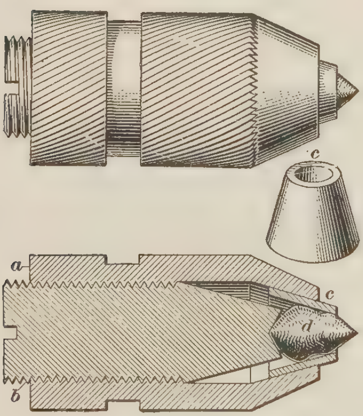


Fig. 73

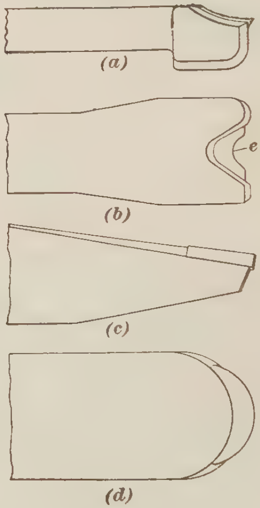


Fig. 74

stone is dull, to reset it. If well taken care of, the diamond tool will work on hard material with much greater cutting speed than the steel tool, and it requires fewer sharpenings. It will leave the work with a smooth, polished finish.

87. Adjustable Diamond-Tool Holders.—In Figs. 72 and 73 are illustrated two types of adjustable holders for diamonds. The clamp holder, shown in Fig. 72, permits the stone *a* to be reground and easily reset when dull; in the holder illustrated in Fig. 73 the outside cap *a* is screwed on a threaded center *b* and causes the taper collar *c* to draw in and hold the stone *d* firmly.

88. Special Diamond Tools.—In Fig. 74 are shown four types of special diamond tools for lathe operations. In (*a*) is shown an end-forming tool, and in (*b*), (*c*), and (*d*) are shown tools for producing an extra-fine glossy surface on grooved metal rolls.

SPECIAL METALS USED FOR LATHE CUTTING TOOLS

89. Stellite.—Stellite is a metal that is extensively used for lathe tools. It is a composition of about 60 per cent. of cobalt, 25 per cent. of tungsten, and 15 per cent. of chromium, and is made in the electric furnace. The tools are cast solid or made with welded tips, and sharpened by grinding. It is more brittle than steel and hence more liable to injury by blows. As it does not lose its hardness even at a dull-red heat, stellite will cut at a greater speed than high-speed steel.

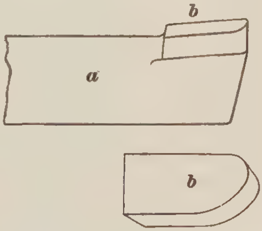


FIG. 75

90. The two softer grades of stellite are used for a variety of lathe tools, including threading tools, and those for cast iron and steel. The third, or hardest, grade is used for turning malleable iron and hard cast iron. This grade is of diamond hardness and tools made of it are ground to a round nose with as much support to the cutting edge as possible. When tools of large section are required, it is economical to use a steel shank *a*, Fig. 75, to which is electric-arc welded a stellite nose *b*. The elastic support of the steel shank enables the tool to be used where a solid stellite tool would probably break from shock.

Straight Face Lathe Tools

Kind of Tool	Face	Angle of Clearance	Kind of Tool	Face	Angle of Clearance	Kind of Tool	Face	Angle of Clearance
Finishing Steel	Side-a	4°	Finishing Cast Iron	Side-a	4°	Bent Finishing Steel	Side-a	4°
	Side-b	4°		Side-b	4°		Side-b	4°
	End-c	6°		End-c	6°		End-c	6°
	Top-d	15°		Top-d	12°		Top-d	15°
Nicking	Side-a	3°	Bent Nicking Right Hand	Side-a	3°	Bent Finishing Cast Iron	Side-a	4°
	Side-b	3°		Side-b	3°		Side-b	4°
	End-c	6°		End-c	6°		End-c	6°
	Top-d	1°		Top-d	1°		Top-d	12°
Side Right Hand	Side-a	6°	Brass Right Hand	Side-a	10°	Brass Bent Right Hand	Side-a	10°
	End-c	6°		Side-b	6°		Side-b	6°
	Top-d	12°		End-c	10°		End-c	10°
				Top-d	0°		Top-d	0°
Bent Side Right Hand	Side-a	6°	Inside Bent Left Hand	Side-a	6°	Square Thread Right Hand	Side-a	10°
	End-c	6°		End-c	6°		Side-b	0°
	Top-d	12°		Top-d	12°		End-c	6°
							Top-d	0°
Square Thread Right Hand	Side-a	10°	60° V Thread Left Hand	Side-a	7°	60° V Thread Bent Right Hand	Side-a	12°
	Side-b	0°		Side-b	12°		Side-b	7°
	End-c	6°		End-c	15°		End-c	15°
	Top-d	0°		Top-d	0°		Top-d	0°

Fig. 76

91. Uranium Steel.—For extremely severe service as, for instance, the turning of chilled-iron rolls, high-speed steel used for making lathe turning tools is alloyed with uranium. The alloying is done in the electric furnace and the liquid steel is poured into molds of the shape of the tool desired. Shaping of the tools is accomplished by grinding.

LATHE-TOOL GRINDING

92. Standard Forms of Lathe Tools.—It has been the practice in machine shops for each lathe operator to grind lathe

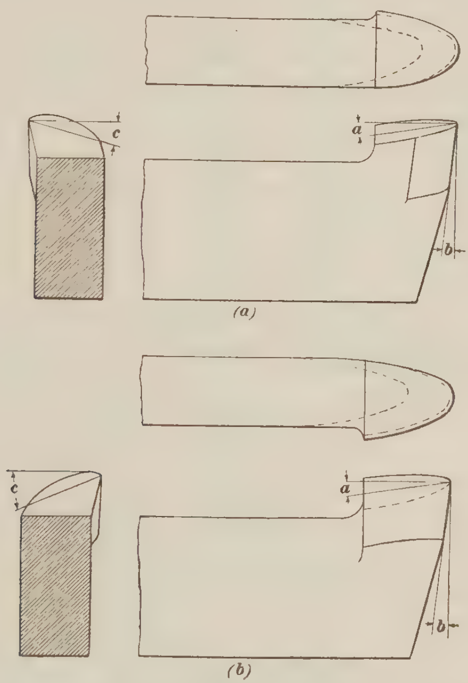
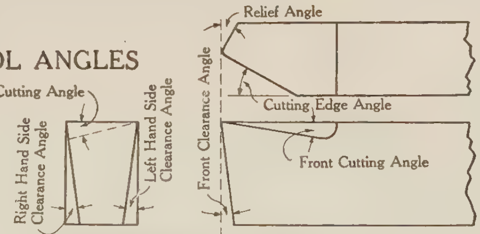


FIG. 77

tools to suit himself, using either grindstones or manufactured abrasive wheels. This method requires a very large stock of steel in order to make up the many sets of tools of different shapes for all the machines. By the modern system the tools

TABLE OF LATHE CUTTING TOOL ANGLES



ARROWS INDICATE DIRECTION OF FEED

TOOL											
NAME		Round Nose Roughing	Straight Roughing	Narrow Finishing	Broad Finishing	Side Roughing and Finishing	Screw Cutting	Bar Turning	Parting	Boring	Brass Turning
Right Hand Side Clearance Angle		3°	0°	6°	6°	0°	0°	0°	2°	0°	6°
Front Clearance Angle		6°	6°	6°	6°	6°	6°	6°	6°	15°	6°
Left Hand Side Clearance Angle		3°	6°	6°	6°	3°	10°	7°	2°	6°	6°
Cutting Edge Angle		10°	35°	0°	0°	5°	30°	0°	0°	35°	30°
Relief Angle		0°	30°	0°	0°	15°		0°	2°	30°	30°
Front Cutting Angle	S.T.	10°	15°	15°	15°	2°	15°	0°	0°	15°	
	C.I.	5°	5°	8°	8°	2°	15°		0°	5°	
Side Cutting Angle	S.T.	15°	22°	0°	0°	20°	0°	35°	0°	22°	
	C.I.	8°	8°	0°	0°	8°	0°		0°	8°	

Fig. 78

are ground, usually on automatic tool-grinding machines, in a central tool room, by one set of men. All tools are kept in the tool room and are checked to the lathe operators as used. By this system the operators do not have their lathes standing idle while awaiting their turn at the grindstone.

93. Typical Roughing and Finishing Lathe Tools. Straight-face forged finishing lathe tools are shown in Fig. 76, together with the angles to which Wm. Sellers and Co. recommend them to be ground. The heavy forged lathe roughing tools are ground by this company as illustrated in Fig. 77. A right-hand tool is shown in (*a*) and a left-hand tool in (*b*). The angles of front top rake *a* are 8°; the clearance angles *b* are 6°, the angle of side top rake *c* is 14° for the right-hand tool and 22° for the left-hand tool. The American Tool Works Co. grind their standard roughing and finishing lathe tools from the unforged bar, as shown in Fig. 78. The method of making lathe tools without forging is becoming quite common

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CHATTERING

94. Description of Chattering.—Chattering of a lathe tool produces a rough corrugated surface on the work, as illustrated in Fig. 79. The tool is caught by the work and drawn in so as to cut deeply; when it has sprung in a certain depth, the tool and the work are placed under a strain that causes them to spring apart. These performances take place in quick succession, and in more or less of a rhythmical order.


Fig. 79

95. Causes of Chatter.—The springing action producing chatter may be traced to different causes: long and slender work; heavy piece on slender arbor; the method of driving or rotating the work; looseness of the spindle in the headstock bearings; looseness in the cross-slide of the tool rest; looseness between the lathe centers; or the peculiar shape or manner of

setting the tool. Also, the chuck may overhang too far beyond the spindle nose, the tool rest may overhang too far, the tool may be set too low, or the compound rest may be too loose.

96. Prevention of Chatter.—Chatter may be prevented in most cases by changing the position of the tool with respect to the work, but the same effect is produced by grinding the tool to a different shape. A slight angle of top side rake given to the tool, sufficient to keep the broad edge of the tool from falling into the old chatter marks, will often prevent or decrease chatter.

Tools with a curved outline are preferred to tools with a broad cutting edge because the tendency of chatter is greater when the chip is uniform, as is the case when broad-nosed tools are used. The tools should be provided with good heel support and should have as little overhang as possible.

97. As chattering necessitates the use of slower cutting speeds it is well to provide for rigid tool support and adequate means of driving the work. Too small lathe dogs should not be used. In turning any piece of cylindrical work whose length is more than 12 times its diameter, a steady rest should be used. To prevent chatter, lathes are made massive enough to absorb all vibrations caused by the cutting operations far beyond the strength requirements. When remedies in the way of adjustment of the tool and the work and methods of driving have been tried without avail, the spring tool often proves successful in preventing the chatter marks.

LATHE PRACTICE

(PART 1)

TURNING ON CENTERS

CYLINDRICAL TURNING

CENTERING

1. Centering Requirements.—In order to turn a piece of work, as shown in Fig. 1, on a lathe, the first step is to center the ends of the work, after which center holes must be drilled and reamed, as shown in Fig. 2 (*a*), so that the work can be held between the centers of the lathe. The operation of locating, drilling, and reaming the center holes is one of importance and requires careful attention. The drilled holes should be deep

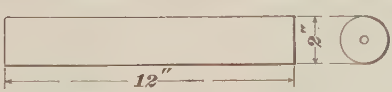


FIG. 1

enough to prevent the points of the lathe centers from touching the bottoms. The reamed hole should exactly fit the lathe centers, which usually have an angle of 60°. When very large center holes are required to support extra-heavy pieces, particularly in cast iron, it is an excellent plan to cut several oil channels *a*, as shown in (*b*). It is also well to fill the end of the center hole *b* with wool, felt, or waste saturated with oil, or fill with heavy grease. White lead thinned with machine oil or light cylinder oil is often used as a lubricant in the work centers.

2. Locating Centers by Dividers.—Various methods are used for locating center holes, depending on the shape of the piece and the number of pieces to be centered. If the stock is

Fig. 2

round and fairly true, the trial center may be located by placing the work on a flat surface and using a pair of dividers, set to about half the diameter of the work, for scribing lines on the end, as shown in Fig. 3. The dividers are drawn across the chalked end of the work, scribing one line; a quarter turn is given to the work and another line is scribed, and so on until there are four lines intersecting, as shown. The center of the square thus formed is approximately the center of the end of the work. The dividers should be held at the same angle with the work each time a line is scribed. A prick-punch mark shall be made in the center of the square for the trial center.

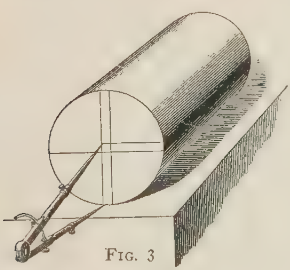


Fig. 3

3. Locating Centers by Surface Gauge.—Instead of the dividers, a surface gauge *a*, Fig. 4, may be used for scribing the lines on a bolt *b*. In this case, it is desirable to make the center true with the stem or shank of the bolt, as the head cannot always be depended on to be forged true with the shank. The bolt is placed in the **V**'s of two blocks *c*, which should hold the bolt high enough from the bench or table that the head will not touch when the bolt is revolved in the **V**'s. The scriber point of the surface gauge is then set to about the center of the work and the four lines are scribed, one at each quarter-turn, intersecting as shown.

4. Locating Centers by Hermaphrodites.—Another method of locating the center is by the use of hermaphrodites, as shown

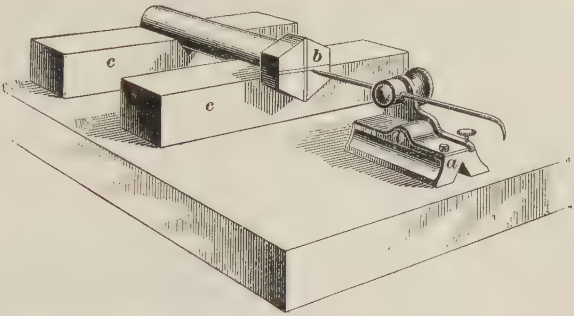


FIG. 4

in Fig. 5. The instrument is set so that the pointed leg comes near the center of the work. With the bent leg at the points *a, b, c,* and *d* on the circumference, four arcs are scribed, intersecting as shown, and forming a small, four-sided central figure. The center *e* of this figure is the approximate center of the end of the work.

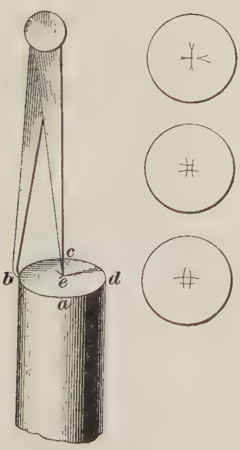


FIG. 5

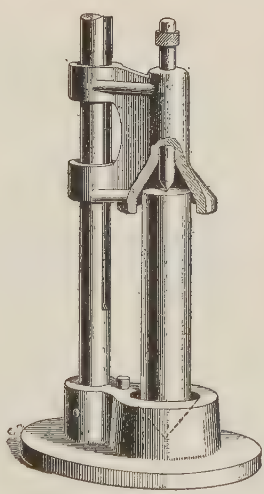
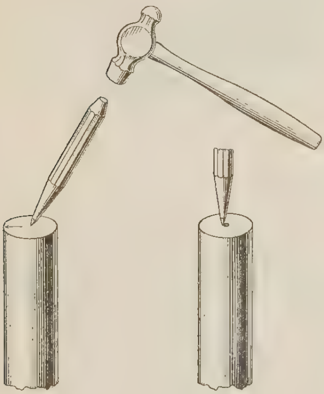


FIG. 6

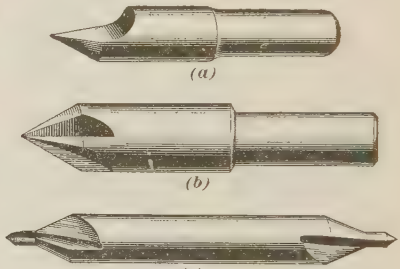
5. Locating Centers by Cup Center.—When there are many small pieces to be centered, time can be saved in locating

the centers by the use of a cup center, shown in Fig. 6. The conical opening in the end is placed over the end of the work, as shown, and a light blow on the prick punch with a hammer is sufficient to mark the center. The end of the work to be centered must be true, and the device held true on the end or it



(a) (b)

FIG. 7



(a) (b) (c)

FIG. 8

will not locate the center accurately. The centering device insures that the punch and the work will be held in line, but does not overcome any errors due to untrue ends. Centers are also located by the use of the center square shown in *Measuring Instruments*.

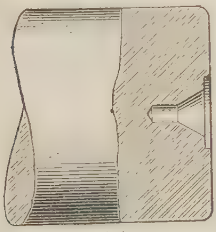
6. Testing Location of Centers.—When the stock, or the rough piece to be finished, is very close to the finished size, it is best to test the accuracy of the location of the centers before they are actually drilled and reamed. In the case of light work this may be done by supporting it between the centers of the lathe, the points of the lathe centers being allowed to enter the prick-punch marks made in the ends of the work. While thus supported, the work should be revolved rapidly by drawing the hand quickly across it. While the work is thus spinning on the center points, chalk is so held close to the ends that it will just touch any high spot on the work. If there is an untrue end or a high side, the chalk will mark the high

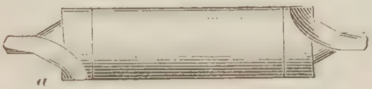
place. The center mark is then moved, until the work will run with sufficient accuracy.

7. Changing Center Marks.—The center marks in the ends may be changed slightly in location by slanting a prick punch in the direction in which it is desired to move the mark and striking a hard blow with a hammer, as shown in Fig. 7 (*a*), or the prick punch may be held at one side of the center, as shown in (*b*). In the latter case, the point of the punch will move toward the old center when struck, but will draw the center to one side, as desired. When the centers are satisfactorily located, they should be made quite large with the punch, for the purpose of making a starting place for the drill, otherwise the drill may not start in the center.

8. Centering Tools.—The tools used to make center holes are a twist drill to form the first or clearance hole and a countersink or center reamer of the form shown in Fig. 8 (*a*) and (*b*), to give the center the correct taper. Most of the small center drilling, however, is done by using the combined drill and reamer shown in (*c*). This tool drills the clearance hole and reams the tapered part true with it.

The drill (*b*), Fig. 9, has two cutting edges *a* on the end of the full-sized body of the drill to make the protected center


(*a*)



(*b*)

FIG. 9

holes, shown in (*a*), which is a very convenient form when facing, especially on the ends of rather large work. The protected hole has an enlarged counterbore at the outer end, as shown, so that the tapered part of the hole is farther inside the work and cannot be injured by the tool or bruised when the work is handled.

9. Making Center Holes.—The ordinary hand process of making correctly formed center holes without special tools consists of feeding a center drill $\frac{1}{16}$ to $\frac{3}{16}$ inch in diameter into the stock deep enough to extend from $\frac{1}{8}$ to $\frac{1}{4}$ inch beyond the point of the lathe center, and then reaming the hole to the angle of the lathe centers. The drills and reamers used should always be proportionate to the size of the work. Small work requires small centers, and large work requires large centers; and they should be larger for high-speed than for carbon-steel tools, in order to give greater support to the work. Table I gives the sizes of center holes for work of given diameters.

TABLE I

SIZES OF CENTER HOLES

Diameter of Work Inches	Size of Drill Inch
$\frac{1}{2}$	$\frac{1}{8}$
1	$\frac{3}{16}$
2	$\frac{5}{16}$
3	$\frac{3}{8}$
6	$\frac{11}{16}$

10. Drilling and Reaming of Center Holes.—If a centering machine is not at hand, the drilling and reaming operations may be done on a sensitive drill, on a speed lathe, or on the engine lathe on which the work is to be turned. It is usually necessary to drill and ream center holes in very large shafts with a ratchet drill or a hand brace while the shafts lie on the floor or are blocked up on the **V**'s of the lathe. When on the **V**'s, a shaft is in line with the centers and the dead spindle is used to feed the drill or reamer.

11. Precautions to Be Taken in Centering Work.—If the bar to be machined is close to size in the rough so that very little stock is left for finishing, care should be taken that it is as straight as possible and that the center holes are located accurately so that the shaft will be true all over when finished. In centering a shaft that is over 3 or 4 pounds in weight, care should be taken to see that the weight of the shaft does not break the center drill. Shafts that are too long to be centered in the lathe may be centered with a breast drill. The regular countersinks may be used in the same manner. For steel or iron pieces oil should be used on the centering drill.

12. Removing Broken Center Drill From Steel Shaft.—If a center drill breaks in a steel shaft, and part of the broken drill remains in the shaft, the broken part may be removed, either by working it out with a chisel or by holding the shaft vertically and striking it lightly with a hammer. If it cannot be dislodged this way, the end of the shaft that has the broken part, should be annealed. The shaft is heated slowly and evenly to a dark red and is then placed in a box of lime or ashes, covered completely and left for about 12 hours. The broken drill will then be soft enough to be removed by drilling.

13. Use of Square Center.—A rough-and-ready method of centering round work, and a very good method for long shafts, is to use the square center shown in Fig. 10. One end of the work is held in the lathe chuck and the other end is allowed to run free if the work is short. If the work is long, the end is supported in a center rest. The square center is placed in the tail spindle and brought against the approximate center of the work. To force the free end of the work to run true, a lathe tool is clamped in the tool post with the smooth butt end of the tool toward the work, and the tool butt is moved slowly against the work. When the work runs true, the tail spindle is advanced until the square center cuts the size of reamed center hole required, allowance being made for what is to be cut off the end of the shaft. As such a center hole has no clearance at the bottom for the point of the lathe center, it should be drilled to make a clear space beyond the bottom of the tapered hole made by the square center.

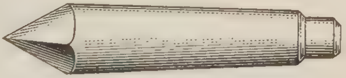


FIG. 10

14. Centering Machines.—When a great deal of work is to be centered, much time and expense can be saved by the use of special centering machines, a type of which is shown in Fig. 11. The use of such a machine makes it unnecessary to locate the centers as just described. The machine illustrated is fitted with a universal chuck *a* that holds the work accurately in line with one spindle of the machine. If the work is long, the end is supported in the **V**-shaped rest *b*, and while in this

position it is drilled and reamed. There are two spindles *c* and *d*, the first carrying a drill and the second a reamer, and these can alternately be brought in line with the center of the work. After the machine is once adjusted, it will drill and ream all pieces to the same depth and size, or one spindle only may be used.

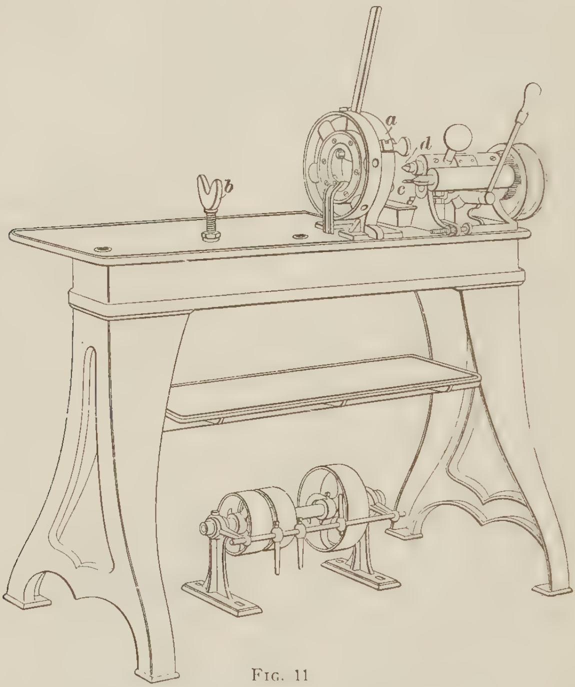


Fig. 11

15. Placing Work on Centers.—After centering and thoroughly cleaning both center holes, the work is ready for the lathe. A lathe dog *a*, shown in Fig. 12, is slipped on the end of the work that is to be supported on the live center *b*, some machine oil is put in the center hole that goes on the dead center *c*, and the tailstock is adjusted to the proper position to hold the work between the centers, as shown. In adjusting the tailstock on the bed, it should be so clamped that it will not be necessary to run the tailstock spindle out very far to reach the

work, as greater stiffness is secured by keeping the spindle well in the tailstock. The work is first placed on the live center and the dead center is carefully run into the center hole.

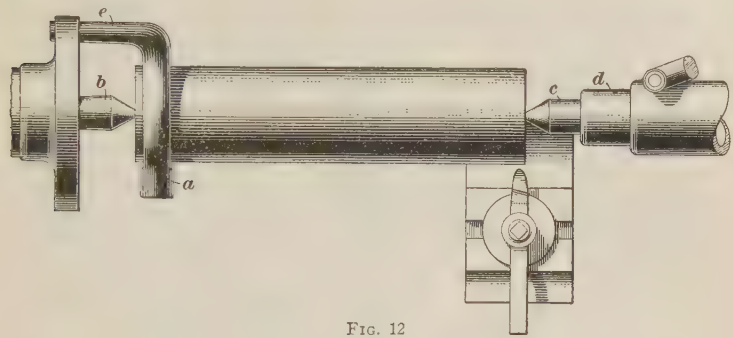


FIG. 12

Care must be taken not to jab the end of the work with the dead center *c* and to adjust the dead center so that the work is free to turn, and at the same time is held so tightly that there is no lost motion. The operator must also see that the tail *e* of the dog fits loosely in the notch of the face plate. Avoid using a dog that is too small, as the tail of the dog may bottom in the face-plate slot and hold the work away from the live center, as shown in Fig. 13. This prevents the work from running true.

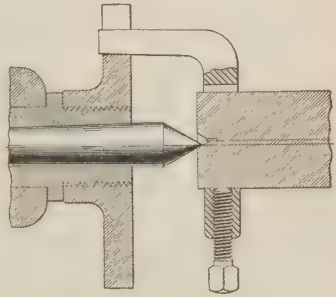


FIG. 13

16. Center Spiders.—Large and long pipes and other hollow work may be held and centered by the use of the center spiders shown in Fig. 14. The center spider consists of a cast-iron body *a* having three arms *b*, into each of which is screwed radially a screw *c* with a pointed head. Each body or spider has a center hole, either drilled and reamed in the body, or made in a steel piece *d* that is hardened and driven into the body. A center spider is placed in each end of the hole, and so adjusted by the screws that the work runs true on the out-

side for turning. A four-arm spider is sometimes used for large work.

17. Bridges in Castings.—When heavy cast work has a tapered cored hole that would make it difficult to use the centers

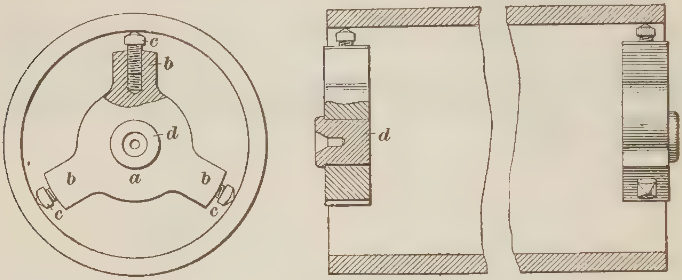


Fig. 14

just described, it is customary to cast a bridge across the end in which the center hole may be placed. Such a bridge is shown at *b*, Fig. 15. A similar bridge should be cast at the other end of the work. After the turning is done, these bridges can

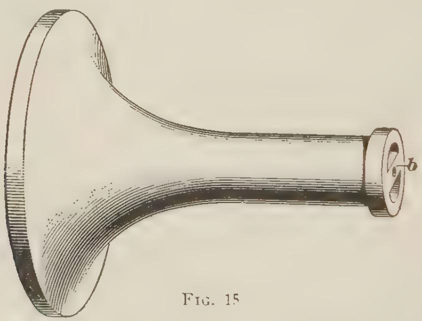


Fig. 15

easily be cut out, if so desired. It is usually better to retain them if they do not interfere with the use of the casting, as their removal sometimes causes the casting to warp.

TAKING THE CUTS

18. Roughing and Finishing Cuts.—On all machine work there are two classes of cuts used, namely, the *roughing cut* and the *finishing cut*. The roughing cut, as its name implies,

is the first heavy cut taken over the work for the purpose of blocking out or roughing the work very close to size, the object being to remove the metal in the shortest possible time. Roughing cuts are, therefore, made as heavy and as deep as the machine will stand. The finishing cut is the last cut taken on the piece and is intended for finishing the work to exact size, and at the same time making it smooth and true. In order to obtain these results, the tool must be very sharp and keen and the cut light.

19. Squaring Ends of Work With Side Tool.—Work that is to be turned between the centers of a lathe should have

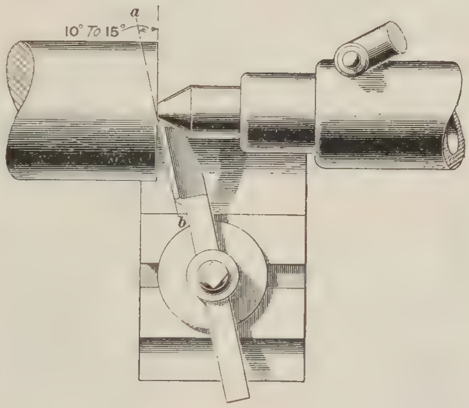


FIG. 16

its ends squared, or made flat and true at right angles to its center line, before the cylindrical surface is turned. The method of squaring the end with the point of the right-hand side tool is shown in Fig. 16. For the roughing cut clamp the side tool in the tool post so that the cutting edge *a b* makes an angle of from 10° to 15° with the end of the work. The tool should be clamped as close to the cutting edge as possible, in order to insure stiffness, and the height should be adjusted so that the cutting edge will be level with the center of the work.

The cut is started at the center of the work. The tool is moved sidewise by moving the carriage by hand until the tool cuts deep enough to get well under the skin and scale, if the

stock is cast iron. The carriage is held stationary in this position while the tool is drawn from the center by means of the cross-feed. These operations are repeated until the desired amount of metal is cut from the end.

20. If much metal is cut from one end, a burr will be left around the center hole, as shown at *b*, Fig. 17. This burr may easily be removed by using the point of the tool, after having first loosened the dead center to admit the tool, as shown. The tool is fed sidewise by hand, in the direction of the arrow, and at the same time the dead center is fed in, to keep the work from dropping off. The small chips that get in the center hole should be carefully removed and the hole oiled, before any turning is done along the cylindrical surface of the work.

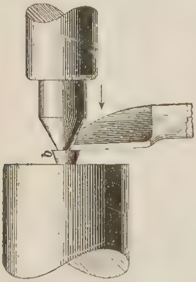


Fig. 17

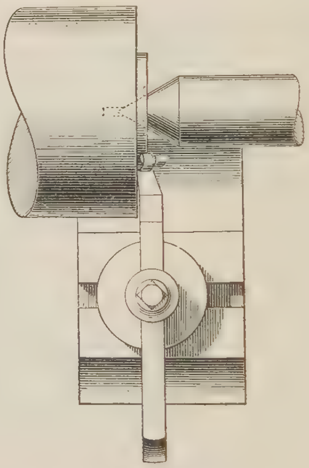


Fig. 18

21. Squaring Ends of Work With Square-Nose Tool.—In the case of large shafts and forgings the rough squaring of the ends is most quickly done, where considerable stock is to be removed, by means of the square-nose tool, Fig. 18. As this tool cannot reach the center hole without injuring the lathe center, the end of the work must be counterbored as shown by the dotted lines. Otherwise the central portion must be turned off by the side tool.

After both ends are roughed off and the piece is very close to the desired length, the center holes should again be drilled

and reamed, if necessary, to make them large enough to stand the strain when the heavy cuts on the outside of the piece are taken.

22. Finishing Cuts With Point of Side Tool.—Before taking a finishing cut on the end of the work, the tool should be reground, if necessary, and then made keen with an oilstone. In order to strengthen the point of the tool and to make the cuts smoother, the cutting edge of the tool is oilstoned with a slight bevel, for about $\frac{1}{8}$ inch from the point, as shown at *a*, Fig. 19. The tool is set the same as for roughing cuts, except that the cutting edge stands at such an angle that the end of the work is flat or tangent to the bevel at the point of the tool. If the point of the tool is not beveled or curved, it will leave deep marks on the work, as shown in Fig. 20, the distance between the marks representing the feed of the tool for each revolution of the work.

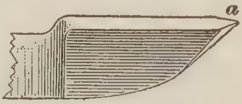


FIG. 19

23. Finishing Cuts With Entire Edge of Side Tool.—In some cases, when the work is small in diameter or when true

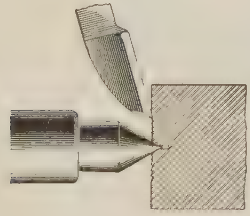


FIG. 20

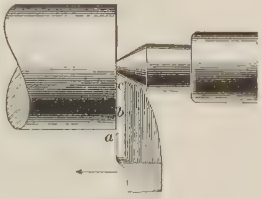


FIG. 21

square faces are not required, the edge *a b c* of the tool is ground straight and set square with the axis of the work, as shown in Fig. 21. When the tool is thus set, it is fed sidewise to the work, in the direction of the arrow, and is not drawn out from the center. The squareness of the end will then depend on the way in which the tool was set.

24. If the tool is set so that only a small part of the edge cuts, and is then drawn out from the center by the cross-feed,

a flat surface will be produced. If, however, in making the cut, the carriage is moved toward or away from the work, or if the tool dulls or shifts in the tool post, the work will not be true. If the lathe continues to make the work concave or convex, that is, either hollow or rounded, the lathe centers will probably be found out of line. After the centers are lined up, the difficulty will probably disappear. The work may be tested with sufficient accuracy for ordinary purposes by putting a scale or straightedge across the end and holding it to the light. If no light can be seen between the surface and the edge of the scale, then the end is true.

25. Roughing Cuts on Cylindrical Work.—The stock to come off should be removed at one cut, whenever possible. In Fig. 22 is shown a tool with top side rake set to take a deep roughing cut. Here the cutting is done along the left-hand edge of the tool, the point doing a very small part. Whether the whole depth can be made or not in one cut depends on the

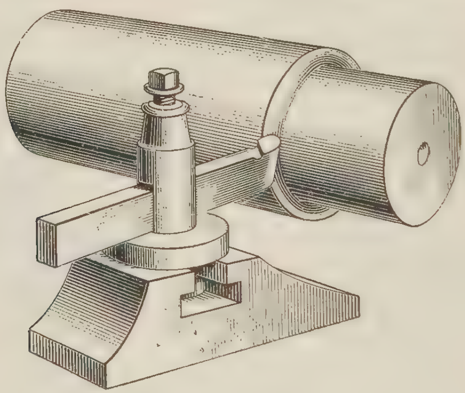


Fig. 22

power of the machine and the strength of the tool, and also on the strength of the piece to withstand a heavy cut without springing or breaking. Some pieces are so frail that a number of light cuts are required to remove an amount of metal that under more favorable conditions could easily be taken off at one cut. Whatever the amount removed may be, there should be left from $\frac{1}{64}$ to $\frac{1}{32}$ inch in diameter over the finished

size for the finishing cut. Only in special cases or on rough work is it allowable to rough and finish work with the same cut.

26. The first roughing cut is started by moving the tool to the end of the work and feeding by hand until it begins to cut. The feed is then thrown in and the tool moves along

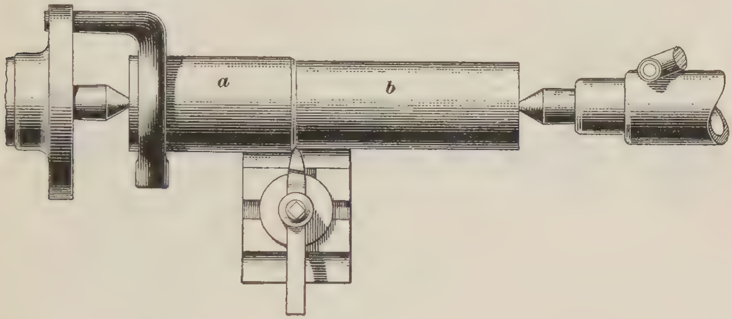


FIG. 23

until a short distance is turned on the end. This part is calipered, and if the cut is not deep enough the tool is set to cut deeper, and another short cut is taken. This process is repeated until the work calipers correctly. The lathe is started, and runs until the tool has fed about half the length of the work, or as far as required. The work will then be as shown in Fig. 23, the part *a* being rough, and the part *b* turned.

27. The tool cannot feed over the entire piece because the lathe dog on the end is in the way. The work should, therefore, be removed from the lathe and the tool and carriage moved back to the starting point, care being taken not to disturb the cross-slide that moves the tool in or out from the work. The dog is changed to the turned end *b*, Fig. 23, the work reversed, and again put in the lathe. This will bring the work as shown in Fig. 24. The rough end *a* is then turned the same as the turned end *b*, and if the cross-feed has not been moved and the work has not sprung, the work will be the same diameter at each end, the two cuts meeting in the middle. When it is necessary to take a number of roughing cuts and accurate work is desired, it is better to reverse the work after each cut,

as just described, then to take a number of cuts on one end before reversing.

28. Testing the Work When Roughing.—During the roughing cut, the work should be calipered along its entire length to see whether it is all of the same diameter. If one end is larger than the other, the lathe centers are out of line, or

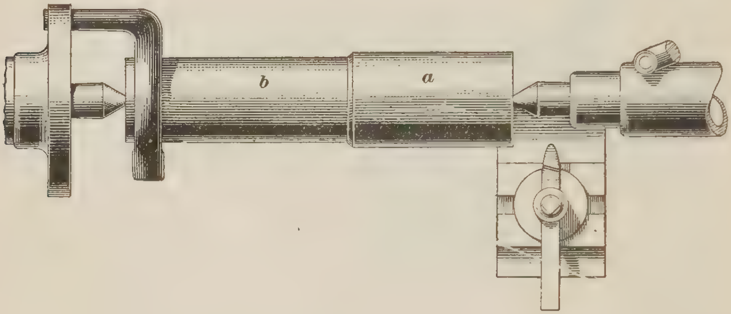


FIG. 24

the tool point is so worn away as to cause a taper. If the centers are out of line, the dead center must be adjusted until the two sides of the work are parallel. Care must be taken, however, to locate the cause correctly, in order that the center may not be moved when the tool is at fault.

29. Finishing Cuts on Cylindrical Work.—In taking the finishing cut, considerable skill must be exercised, for if the piece is turned too small, there is no remedy, and if cut rough and untrue, it requires extra labor to complete it. The tool should always be resharpened for the finishing cut. Its shape remains much the same as for roughing, except that the top face may have a little more slant or top rake. The shapes of tools and also the feed vary considerably, so that what may be considered good practice for a small piece would not be the best for heavier work.

30. Measuring Diameter of Work With Calipers.—The diameter of the work is measured either by special gauges or by calipers. Where the work is larger than the capacity of the available micrometer calipers, the ordinary calipers are gener-

ally used. When calipers are used, they are adjusted to correct size by trying them over a standard cylindrical gauge of the desired size, or they may be set to size by the use of a scale. In the latter case, they should be so held that the point of one leg of the calipers comes against the end of the scale, and by means of the thumb nut, the calipers are so adjusted that the point of the other leg comes even with the desired line on the scale. Care must be taken to hold the calipers true and to make the adjustment such that by looking squarely by the point of the calipers, it will appear to split the mark on the scale. The thickness of a line on a steel scale is about .002 or .003 inch, and in many instances this amount would be sufficient to spoil a fit. Steel gauges or calipers should never be tried on the work while it is running.

31. Care in Calipering.—Great skill and delicacy of touch may be acquired by careful calipering, and differences in diameter of .001 inch or less may be detected with ordinary spring calipers. There are two chances for error in calipering, namely, by incorrect setting, and by improper handling of the calipers. When the calipers are correctly adjusted, they are held lightly at the joint between the thumb and fingers of one hand, and one leg guided with the other hand, as shown in Fig. 25, and passed gently over the work a number of times.

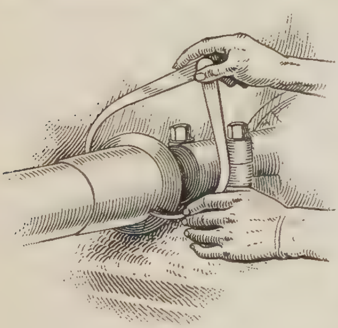


FIG. 25

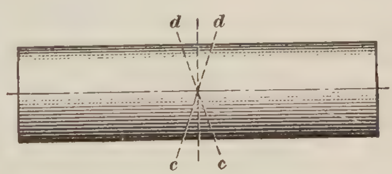


FIG. 26

On small work only one hand is necessary to hold the calipers. It is obvious that the diameter of a cylinder must be measured at right angles to its axis, and if measured at any other angle, as along the line *c d*, Fig. 26, it would be incorrect. The calipers are, therefore, turned slightly from side to side until the

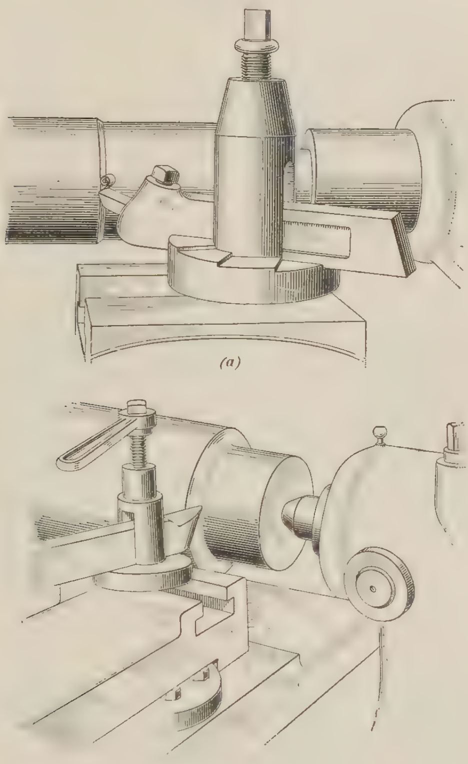
position is found where they pass over most easily. This position, which appears to be the smallest diameter, is the correct one. When the work is of the correct size and the correct position is found, the calipers will just pass over with a very gentle pressure. If the pressure is sufficient to hold the weight of the calipers or if force is required to push them over the work, it is too large.

32. Calipers may very easily be sprung, and it is an easy matter to force a large pair over work $\frac{1}{16}$ or $\frac{1}{8}$ inch too large. When they have been set from a gauge, the work should be turned so that they fit the work with the same pressure and feeling that they fit the gauge. When large calipers are being set, they should be held in the same position in which they will be held on the work. If a pair of large calipers is held in a horizontal position, is set to a pin gauge lying on the bench, and is then held upright by the joint, the legs will spring enough by their own weight to bring the measuring points closer together, and work turned to them will be too small.

33. Setting Tool to Finish a Required Diameter.—The finishing tool is set to turn the correct diameter by a series of careful trials. A light cut is first taken on the end and run along far enough to give sufficient length of turned part to caliper. The lathe is stopped and this part is carefully calipered. If it is found too large, the lathe is again started, the feed thrown out, and the carriage and tool moved back to the starting point. The tool is moved forwards an amount determined by the judgment of the operator and another cut is taken. The work is again calipered, and if still too large, the operation is repeated until the correct diameter is obtained, when the lathe is started, and the cut taken the required distance. When by calipering it is found necessary to take another cut, the cross-feed screw must be used only to advance the tool. If the tool is displaced, the operator cannot estimate how much to turn the cross-feed screw to move the tool in a little deeper.

34. Position of Tool.—The tool should be clamped in the tool post as close to the cutting edge as possible, to make it

rigid. The shank is usually set at about right angles to the work during roughing, as was shown in Figs. 23 and 24, but for heavy roughing operations on very hard steel with high-speed-steel tools the shanks may be set at an angle to the work, as shown in Fig. 27. Such tools should be ground



(b)

Fig. 27

according to their setting with respect to the work. The position of the high-speed-steel cutter, as shown in (*a*), requires the tool to be set with top front rake and plenty of ground front clearance. The tool in (*b*) should have top side rake and side clearance. This tool cuts thin chips of greater width but not at so high a speed.

35. Height of Point Above Centers.—The height of the point above the center of the work is governed by the diameter of the work and the angle of clearance. In Fig. 28 a tool is shown set at the correct height for turning a piece to the

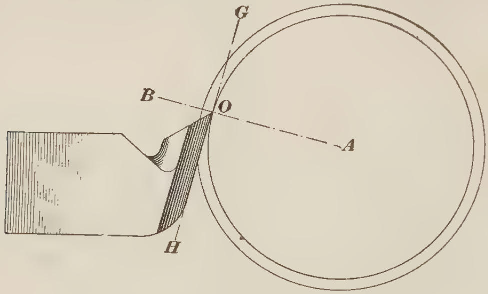


FIG. 28

diameter shown by the inner circle; that is, it is set so that a line *A B* drawn from the center through the point *O* of the tool will be at right angles to the front edge *G H* of the tool. If the tool should be raised, its front being kept at the same angle to the work, it would bring the cutting point above the work, as shown in Fig. 29. It is plain that in this position it would be impossible for the tool to cut. Fig. 28 shows the exact position for a perfect tool, provided it would remain sharp.

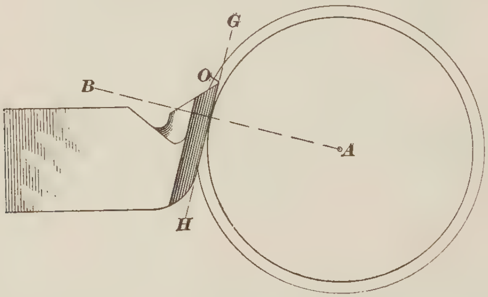


FIG. 29

36. In practice, the tool dulls and the point rounds off slightly, so that it is customary to set the tool slightly below this position. This theoretical height varies with every diameter of work. In Fig. 30 is shown a tool correctly set for a

piece of large diameter. The dotted lines show the same tool at the same height moved in to cut on a smaller piece shown by the dotted lines. It will be seen that the tool cannot cut work of such small diameter when its point O' is so far above the center. It will also be seen that the point of the tool should be lowered as the diameter decreases, the point O following along the radial line $A\ B$ until it finally reaches the axis of the work.

37. Clamping the Tool.—When the tool is being clamped in the tool post, care should be taken to see that the point of

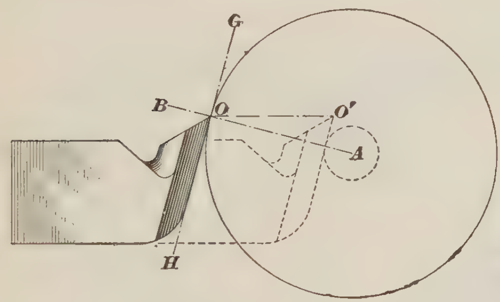


FIG. 30

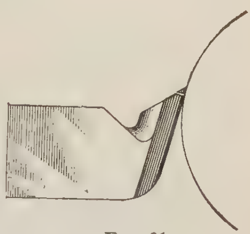


FIG. 31

the tool does not touch the work. When it does touch and the tool clamp is tightened, the edge is liable to be cracked off, as shown in Fig. 31.

RADIAL FACING

38. Definition.—When a true flat surface at right angles to the line of centers is turned in a lathe, on work held in a chuck, or a face plate, or between centers, the operation is called *radial facing;* for example, squaring up the ends of a piece of work held between centers is radial facing.

39. Facing of Revolving Work.—There are two important points in all facing. First, all end play of the lathe spindle must be taken up. Second, the carriage must be clamped on the **V**'s, which prevents the tool from moving away from the work. If the work is held in a chuck or on the face plate,

the ordinary turning tools such as either the round-nose or the diamond tools may be used and set facing the face plate squarely, as in Fig. 32. If the arbor or a mandrel is in the way, the tool may be set as in Fig. 33, though, if so set with the edge *E F* inclined toward the tail center and the tool slips at all, it will dig into the work.

Tools for radial facing are shaped and ground with a clearance of from 5 to 8 degrees on the front face, and the clearance on the side that cuts should be enough more to allow for

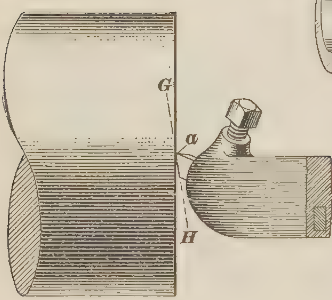


Fig. 32

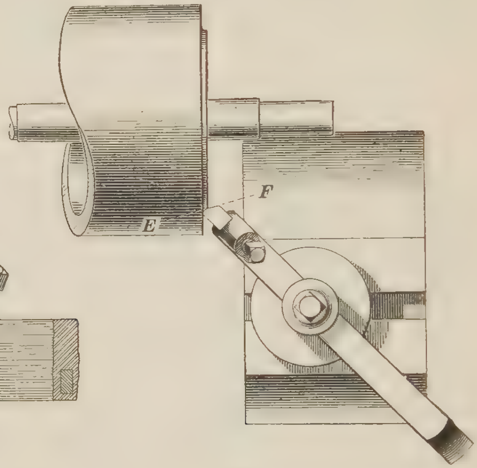


Fig. 33

the feed to be used. It is usually better to set the tools level with the centers, but if there is a hole through the work the tool may be set a little above the center. A straight round-nosed tool is desirable for turning the piece shown in Fig. 34, as it can be set to turn the round part *a* and face the flat face *b* without resetting.

40. Cutting Speed in Radial Facing.—In radial facing, the cutting speed of the tool will vary according to the diameter of the work at the point where the tool is operating, the number of revolutions per minute remaining the same; hence, it is evident that, as the tool advances toward the center, the cutting speed will decrease. For this reason, on large sur-

faces, it is advantageous to speed up the lathe as the tool advances toward the center.

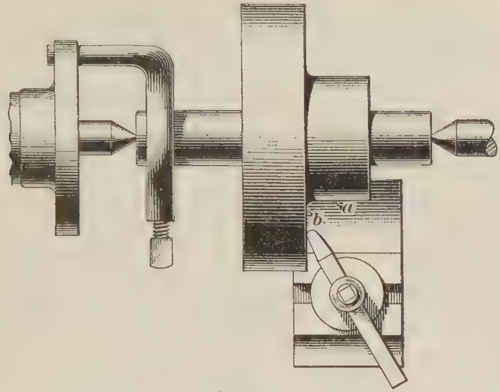


Fig. 34

41. Facing of Stationary Work.—When the work to be operated on is so large that it cannot be swung on the face plate, it must be blocked up to the proper position and bolted

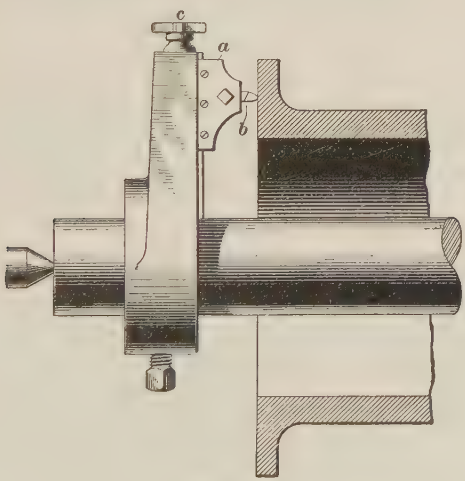


Fig. 35

to the carriage or lathe bed securely, so that there will be no chance of its moving during the facing. It is faced by means of a tool, or cutter, on a rotating arm.

42. Facing Arms.—For facing the ends of cylinders a facing arm is used, as shown in Fig. 35. The arm is fastened to, and rotates with, the boring bar. On one side is fitted a tool block *a* that slides on a guide, and that carries the cutting tool *b*. Feed-motion is given by means of a screw operated by the star wheel *c*, which is made to rotate partly for each revolution of the bar, either by hand or by means of a pin fastened to the machine so that the pin engages the points on the wheel as the arm revolves. In this way, the tool is fed entirely across the face of the work. When a facing arm is not at hand, a cross-slide of some sort is fastened to the face plate of the lathe. Very often the compound rest is so fastened to the face plate that the slide may be used for feeding a tool across the face of the work.

43. When a large piece of work held either in a chuck or on a face plate is to be bored and faced, as in Fig. 35, it is best to do the facing and outside rough turning before doing the boring. A better chance is thus given to start chucking tools and a better edge is furnished for calipering the hole; also, in facing, the tool *b* is farther from the center line of the work than in boring, and, therefore, the facing tool has a greater leverage on the work. Hence, if the chucking is secure enough to stand the facing operation, it will hold during the boring operation and there will be the least risk of spoiling the work.

TURNING LONG WORK

44. Steady Rest.—When long shafts are to be turned, it is necessary to support them along their length; otherwise, they will bend and vibrate so that it will be very difficult to take a cut from them. In Fig. 36 is shown a steady rest that is supplied with engine lathes. When in use, this rest is bolted to the top of the lathe bed at a place where it is desired to support the shaft. The rest is made in two parts, with a hinge *a* at the back and a latch or clamp *b* at the front. After the steady rest is clamped on the bed, the latch is unclamped, the top half turned back, and the jaws moved so far from the

center that they will not touch the shaft. The shaft can next be put in the lathe between the centers.

45. For long shafts this rest should be set up first near the tailstock and all three jaws set up snugly against the shaft. The top is then swung back by loosening the catch *b* and swinging it on the hinge *a*, Fig. 36. The whole steady rest is then slid along the **V**'s to the desired position and the top

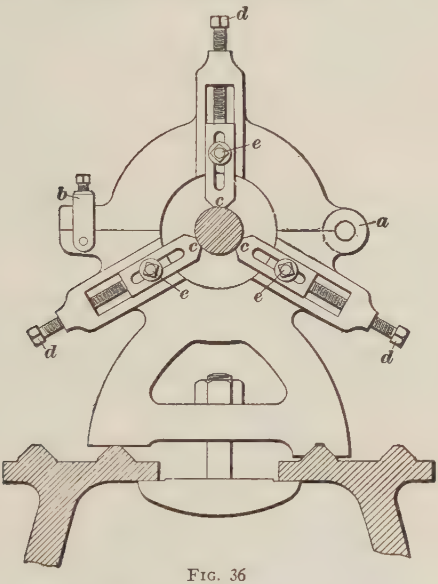


FIG. 36

swung back. If it is too tight the screw at *b* may be loosened slightly so that the shaft turns freely. Care should be taken that the center line of the shaft be in line with the lathe centers, otherwise the tool will not cut to the correct diameter.

46. In Fig. 37 is shown a method of holding a bar when it is desired to operate on the end for boring operations. In adjusting a steady rest, the bar is held by one end in the chuck and adjusted to run true, and the other end is supported on the dead center. The steady rest is moved very close to the dead center and the jaws are moved to touch the bar. Without changing the adjustment of the jaws the steady

rest is then opened by turning back the top, and moved a little distance from the dead center. After the tailstock has been run back to make room for the boring tool the work will still

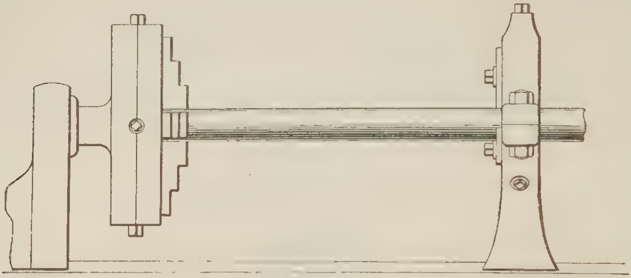


Fig. 37

be in line with the headstock spindle. This method of supporting work is often used for very large pieces, and, when necessary, very large and heavy steady rests are used.

47. Steady Rest of Heavy Design.—The forging for a large gun is usually operated on while one end is supported in and driven by a chuck, and the body of the piece is upheld by

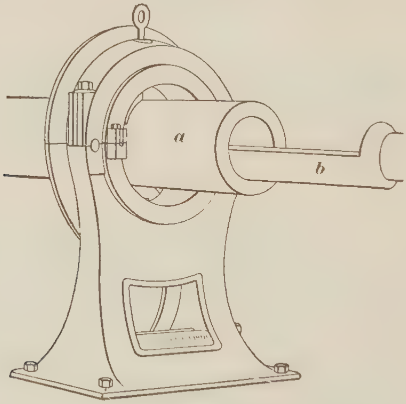


Fig. 38

one or more steady rests of an especially heavy design. Fig. 38 illustrates one of them supporting the inner tube for a 12-inch gun, *a* being the tube and *b* a large cannon drill used for boring the inside of the tube. In gun work, the roughing and finish-

ing tools are specially designed drills and reamers, and the cutting speeds are very slow.

48. Spotting of Shaft.—If the shaft is not already perfectly round, as in the case of bars or forgings, it may be necessary to spot a place for the steady rest. This means that a short length of the shaft is turned true and somewhat larger than its finished size, by means of a very light cut and then the center rest is adjusted to it, care being taken to get it in line with the centers.

If the shaft is quite long and slender and it is desired to put the steady rest near the middle of the shaft, it may be

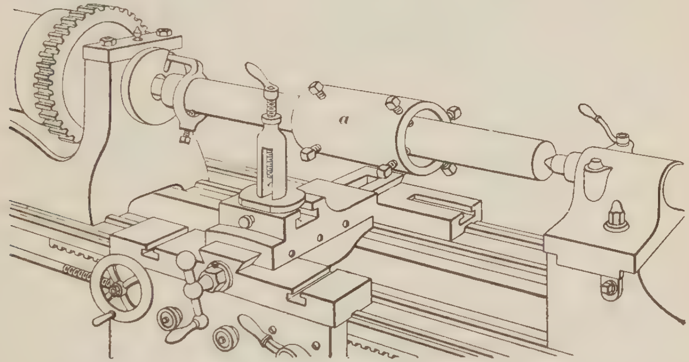


FIG. 39

found that the shaft cannot at once be spotted in the middle because of its flexibility. Cuts may be taken near the end of the shaft, where it is better supported by the lathe centers, and the spring is less. In such a case, a cut would be taken near the dead center and a spot made. When the shaft is thus spotted, the steady rest may be adjusted to this place and the second spot turned farther along. In this way the spots may be moved along the shaft until the middle is reached.

49. Cat Head.—On some classes of work, such as rough shafts, it may be desired to use the steady rest on a part that does not run true, and it is not desirable, or possible, to spot the place on the shaft. In such a case, a sleeve, or *cat head,* illustrated at *a,* Fig. 39, is adjusted to run true on the shaft

by a number of setscrews, as shown. This device may be used on square work or on any piece of work that does not have a true surface or that cannot be spotted for a steady rest.

50. After the cat head has been set, the jaws of the steady rest may be adjusted to it the same as to a larger shaft. In

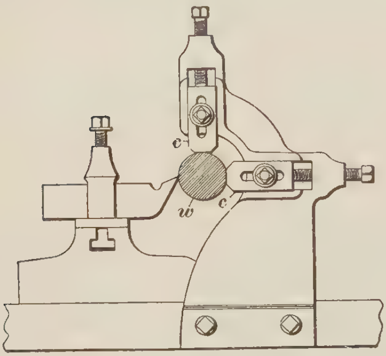


FIG. 40

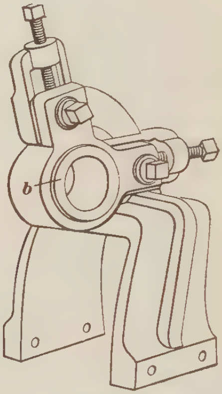


FIG. 41

the case of the slender shaft, the cat head may be used instead of making the series of spots from the end. If the shaft is long, it may be necessary to use two or more steady rests. When the tool and carriage have fed up to the steady rest it must be moved to another position to allow the cut to pass.

51. Follow Rest.—Another method of supporting shafts while being turned is by the use of the follow rest, as shown in Fig. 40. This rest is bolted securely to the carriage and travels with it. When it is used, a cut of the desired diameter is started at the end of the shaft. As soon as a spot is made true, the two jaws *c* are carefully adjusted to the work *w*. As there is a tendency to spring the shaft away from the tool, two jaws are sufficient to support the work, but a third supporting jaw is sometimes used to advantage in some follow rests underneath the shaft to keep it from chattering. It is desirable to have some support under the shaft if it is long and slender because if for some reason the lathe is stopped, the shaft may readily happen to drop down between the cutting

tool and the jaw *c* at the back and when the lathe is started up again there may be trouble.

52. Solid Bushings.—Another method of supporting the work is by means of the follow rest supplied with a set of bushings, so that as soon as the end of the shaft is turned, it enters a rigid bearing. Such a follow rest is shown in Fig. 41. Bushings *b* bored to different diameters are used for different sizes of shafts. This style of follow rest gives a very perfect support for the shaft. When used, the tool is set slightly in advance of the rest. The closer the tool is set to the follow rest, the less danger there is of its chattering.

This form of follow rest requires much more careful watching than the others since if the work is allowed to run large the shaft will catch and grind into the bushing, ruining both, whereas if it runs small the shaft will chatter. The work should be calipered constantly while the rest is being used.

53. Follow Rest for a Shafting Lathe.—When much shafting is to be turned, it is a convenience to use a special shafting turner, as shown in Fig. 42. This has a follow rest *a*

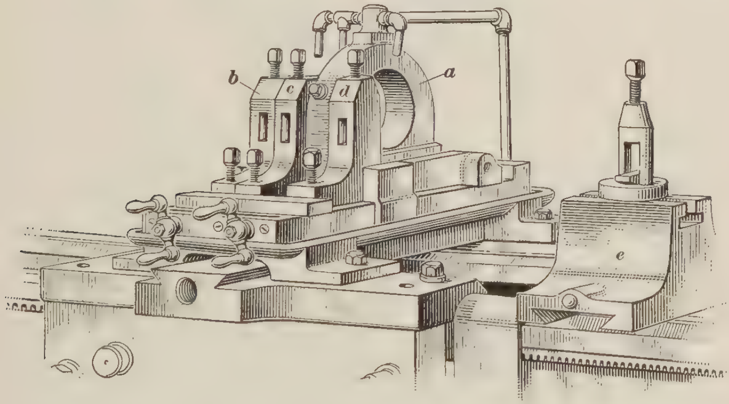


FIG. 42

having a large hole in which a bushing to fit the shaft is set, similar to that shown in Fig. 41. Three or more independent tool slides *b*, *c*, and *d* are used so that a number of tools may cut at once. The two roughing-tool slides *b* and *c* precede the

follow rest *a*, and the finishing-tool slide *d* follows the rest *a*. The shaft is thus roughed and finished at one pass of the carriage, and with a feed of 4 or 5 to the inch. The regular tool slide is shown set aside at *e*.

54. Use of Parting Tool.—Work held between centers should not be cut entirely in two by a parting tool. It may be cut partly in two, after which it should be taken from the lathe and either broken or sawed apart. In Fig. 43 is shown the tool deep in a cut. Soon the piece will become so reduced in diameter that the pressure due to the feed will bend the work,

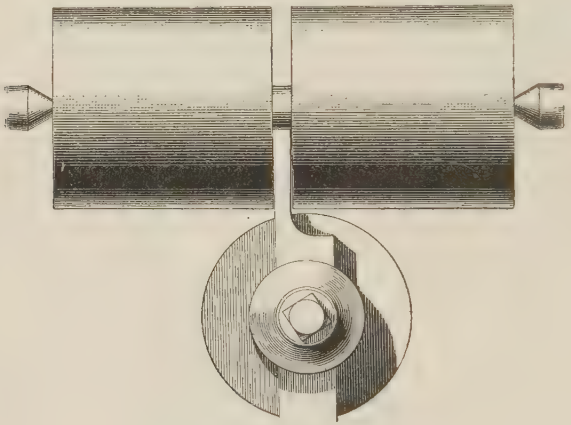


FIG. 43

which, at this small diameter, will open the cut on one side and close it on the other, so that the tool cannot pass through and will become jammed in the cut. This may break the tool, or the lathe center may be broken, or the center hole damaged.

55. When it is desired to cut work very close to a shoulder or the jaws of a chuck, a bent parting tool may be used, as shown in Fig. 44. The offset parting tool holder is particularly well adapted to this class of work.

56. Straightening Machines.—After the shafts are turned, they are apt to be crooked from the release of the surface tension. They may be straightened on a regular shafting

straightener, which consists of a number of conical rolls so arranged that, as the shaft is revolved and drawn between them, it is bent and straightened. This is only used where large quantities of shafting are made.

57. Straightening Small Work.—A special straightener is not always necessary to straighten a shaft. Small straightening presses may be used for bending a crooked shaft to make it straight. These straightening presses are so constructed that the shaft to be straightened rests on two supports from 1 to 3 feet apart, depending on the size of the straightener. An arm projects from behind the machine, midway between the points of support, and over the shaft in such a way that a vertical

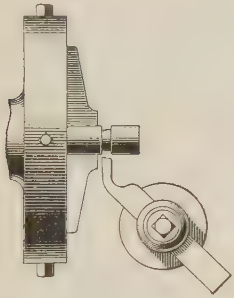


FIG. 44

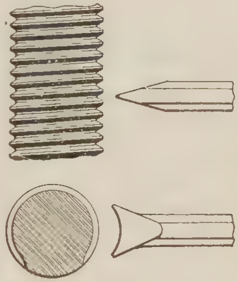


FIG. 45

screw may be used for pressing the shaft down. The shaft to be straightened is supported between the centers of the lathe, and while revolved by hand is marked with chalk on the high side. It is then removed from the lathe to the straightener and bent sufficiently to make it straight. A number of trials may be necessary to make the shaft run true. If the bend is a short kink, then all the straightening should be done at that place; but, if the original crook is a long sweep, the work should be straightened by a series of applications of the press along the work.

58. The press is sometimes supported on wheels and set directly on the lathe bed. After the work is tested, the press is moved along the bed to the crooked place on the shaft, and, after the lathe centers are loosened, the machine is used for

straightening the work. If a press is not at hand, a shaft may be straightened after marking by taking it from the lathe and resting it on two solid blocks of wood, with the marked part up between the blocks. A third block is placed on the shaft between the supporting blocks, and is given a blow with a hammer or sledge. Care must be taken not to deliver too heavy a blow, or the work will be more crooked than before.

59. Sometimes, when the proper straightening devices are not at hand, slender work may be straightened between the lathe centers; but such practice injures the lathe centers and should not be used except in special cases. The work is revolved between the lathe centers and the high side marked. A bar or lever is then put over a tool in the tool post and under the work in such a way that when the lever is pushed down by hand the work will be sprung up. By turning the work so that the marked part is down, it can be so sprung that, after a number of trials, it will run quite true. If the bend is long and uniform, it can be straightened by simply bending or springing the bar as just indicated. If the shaft appears to have a short bend, while either side of the bend appears to be straight, this short bend can be taken out by springing the shaft with the lever, as described, and striking a few blows with the hammer on a piece of sheet brass or copper placed on the top of the shaft on the bent part. The hammering should be light at first, or the bar will be bent as badly as it was before, but to the opposite side. This hammering has a peening action that tends to stretch the shaft slightly on the side struck.

60. Straightening Lead Screws.—Peening is sometimes used for straightening large or long lathe lead screws after they have been threaded. A special tool is used for peening between the threads, as shown in Fig. 45. It is made thin at its edge, so that it will go loosely between the threads down to the root, and is concave, so that it fits around the screw for a short distance. The screw is tested and the untrue spot located. The high part is turned down and sprung up with the lever at the bent place, and, while held in this sprung position, a few of the spaces between the threads on the top side are peened with the

peening tool and a hammer. With some skill, a screw that is badly bent may be quickly straightened. This method of straightening screws will not do when the pitch of the lead screw must be accurate, because it will stretch the screw slightly. For ordinary purposes, however, the stretching of the screw caused by slight peening would scarcely be perceptible. The most accurate lead screws are always straightened without peening, and the finishing cut is taken on the sides of the threads without disturbing the core.

TAPER TURNING

KINDS OF TAPER USED

61. Definition of Taper on Turned Work.—In lathe work the word *taper* means that the piece is turned down so as gradually to diminish in size from end to end. The taper is

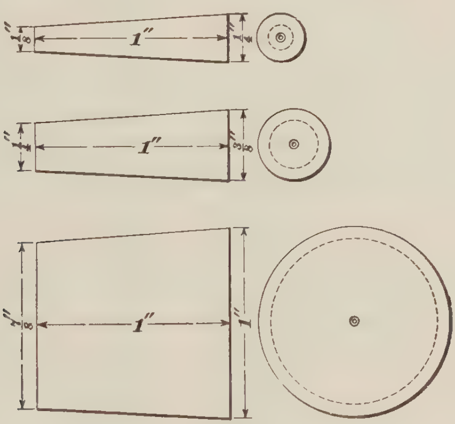


Fig. 46

expressed as the rate in inches that the size changes in diameter to 1 inch or to 1 foot of length of the piece. Thus, in Fig. 46 three equal tapers of $\frac{1}{8}$ inch per inch on pieces of unequal diameters, are shown. Also, in Fig. 47, three equal tapers of $\frac{1}{8}$ inch per inch on pieces of unequal lengths are shown. In any case the taper per foot is 12 times the taper per inch, or in these cases

it is 12 times $\frac{1}{8}$, which equals $1\frac{1}{2}$ inches taper per foot. On the other hand, taper per foot may be changed to taper per inch by

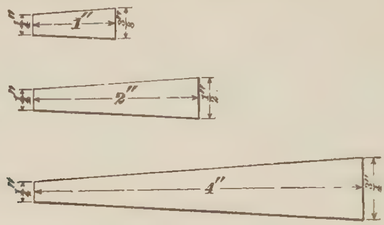


Fig. 47

dividing by 12. Thus, a taper of $1\frac{1}{2}$ inches per foot is the same as $1\frac{1}{2}$ divided by 12, or $\frac{1}{8}$ inch per inch.

TABLE II

BROWN & SHARPE STANDARD TAPER OF $\frac{1}{2}$ INCH PER FOOT

No. of taper.......	1	2	3	4	5	6	7	8	9
Dia. at small end..	.20"	.25"	.312"	.35"	.45"	.50"	.60"	.75"	.90"
No. of taper.......	10	11	12	13	14	15	16	17	18
Dia. at small end..	1.05"	1.25"	1.50"	1.75"	2"	2.25"	2.50"	2.75"	3"

62. Standard Tapers.—Tapers are often spoken of by numbers or by the names of particular makers, as, for example, the Brown & Sharpe, or the Morse tapers of a given number. The Brown & Sharpe taper is $\frac{1}{2}$ inch to 1 foot, and the number

TABLE III

MORSE TAPER OF $\frac{5}{8}$ INCH PER FOOT

Number of Taper	Diameter at Small End	Taper per Foot	Taper per Inch
0	.252	.625	.05208
1	.369	.600	.05000
2	.572	.602	.05016
3	.778	.602	.05016
4	1.020	.623	.05191
5	1.475	.630	.05250
6	2.116	.626	.05216
7	2.750	.625	.05208

TABLE IV

THE REED TAPER OF .6 INCH PER FOOT, OR .05 INCH PER INCH

Diameter Small End	Length of Taper
$\frac{9}{16}$	$3\frac{5}{8}$
$\frac{15}{16}$	$4\frac{1}{8}$
$1\frac{1}{4}$	$4\frac{1}{8}$
$1\frac{3}{4}$	$4\frac{3}{8}$
$1\frac{1}{2}$	$5\frac{5}{16}$
$1\frac{3}{4}$	$5\frac{1}{2}$
2	$5\frac{3}{4}$

TABLE V

THE JARNO TAPER OF .6 INCH PER FOOT, OR .05 INCH PER INCH

No. of Taper	Diameter Small End	Diameter Large End	Length of Taper
1	.10	.125	.5
2	.20	.250	1.0
3	.30	.375	1.5
4	.40	.500	2.0
5	.50	.625	2.5
6	.60	.750	3.0
7	.70	.875	3.5
8	.80	1.000	4.0
9	.90	1.125	4.5
10	1.00	1.250	5.0
11	1.10	1.375	5.5
12	1.20	1.500	6.0
13	1.30	1.625	6.5
14	1.40	1.750	7.0
15	1.50	1.875	7.5
16	1.60	2.000	8.0
17	1.70	2.125	8.5
18	1.80	2.250	9.0
19	1.90	2.375	9.5
20	2.00	2.500	10.0

of the taper indicates a particular diameter at the small end. The Morse taper is $\frac{5}{8}$ inch to 1 foot, and the numbers indicate different sizes. Unfortunately, the first standards were slightly inaccurate, and consequently only the Morse tapers Nos. 0 and 7 are exactly $\frac{5}{8}$ inch to 1 foot. The taper of pipe threads is $\frac{3}{4}$ inch per foot, which is called the Briggs standard.

63. The Jarno and the Reed tapers are .6 inch to 1 foot, or 1 in 20. The Sellers taper is $\frac{3}{4}$ inch to 1 foot. The Pratt

TABLE VI

PRATT AND WHITNEY TAPER OF $\frac{1}{4}$ INCH PER FOOT, OR .0208 INCH PER INCH FOR PINS AND REAMERS

No. of Taper	Diameter Small End Reamer	Diameter Large End Reamer	Length of Taper	Diameter Large End of Pin	Length of Pin
0	0.135	.162	$1\frac{5}{16}$	.156	1
1	.146	.179	$1\frac{9}{16}$	.172	$1\frac{1}{4}$
2	.162	.200	$1\frac{13}{16}$	.193	$1\frac{1}{2}$
3	.183	.226	$2\frac{1}{16}$	.219	$1\frac{3}{4}$
4	.208	.257	$2\frac{3}{8}$	.250	2
5	.240	.300	$2\frac{7}{8}$	.289	$2\frac{1}{4}$
6	.279	.354	$3\frac{5}{8}$	.341	$3\frac{1}{4}$
7	.331	.423	$4\frac{7}{16}$	.409	$3\frac{3}{4}$
8	.398	.507	$5\frac{1}{4}$	.492	$4\frac{1}{2}$
9	.482	.609	$6\frac{1}{8}$	.591	$5\frac{1}{4}$
10	.581	.727	7	.706	6
11	.706	.878	$8\frac{1}{4}$	.857	$7\frac{1}{4}$
12	.842	1.050	10	1.013	$8\frac{3}{4}$
13	1.009	1.259	12	1.233	$10\frac{3}{4}$

and Whitney taper for reamers and pins is $\frac{1}{4}$ inch to 1 foot, or .0208 inch to 1 inch. Tables II to VII give the data of these tapers.

64. The number of the Jarno taper indicates all the dimensions, so that a table need not be used. Thus, the taper number is the number of eighths of an inch in the diameter of the large end, the number of tenths of an inch in the diameter of the small

TABLE VII

TAPERS PER FOOT IN INCHES AND CORRESPONDING ANGLES

Taper per Foot	Total Included Angle *a*		Angle With Center Line *b*		Taper per Inch	Taper per Inch From Center Line
	Deg.	Min.	Deg.	Min.		
1/64	0	4½	0	2¼	.001302	.000651
1/32	0	9	0	4½	.002604	.001302
1/16	0	18	0	9	.005205	.026041
3/32	0	27	0	13½	.007812	.003906
1/8	0	36	0	18	.010416	.005203
3/16	0	54	0	27	.015625	.007812
1/4	1	12	0	36	.020833	.010416
5/16	1	30	0	45	.026042	.013021
3/8	1	47	0	53	.031250	.015625
7/16	2	05	1	02	.036458	.018229
1/2	2	23	1	11	.041667	.020833
9/16	2	42	1	21	.046875	.023438
5/8	3	00	1	30	.052084	.026042
11/16	3	18	1	39	.057292	.028646
3/4	3	25	1	47	.062500	.031250
13/16	3	52	1	56	.067708	.033854
7/8	4	12	2	06	.072917	.036456
15/16	4	28	2	14	.078125	.039063
1	4	45	2	23	.083330	.041667
1¼	5	58	2	59	.104666	.052084
1½	7	08	3	34	.125000	.062500
1¾	8	20	4	10	.145833	.072917
2	9	32	4	46	.166666	.083332
2½	11	54	5	57	.208333	.104166
3	14	16	7	08	.250000	.125000
3½	16	36	8	18	.291666	.145833
4	18	54	9	27	.333333	.166666
4½	21	40	10	50	.375000	.187500
5	24	04	12	02	.416666	.208333
6	28	06	14	03	.500000	.250000

ends, and the number of halves of an inch in the length of the taper. Hence, the length of the taper equals the number of taper divided by 2, the diameter at the large end equals the number of taper divided by 8, and the diameter at the small end equals the number of taper divided by 10.

COMPUTING TAPERS

65. Included-Angle Problems.—Table VII shows the relation between the taper in inches per foot and the taper in degrees. When a taper, having a length *l*, as in Fig. 48, is turned in a lathe to a diameter *A* at the large end, and a diameter *B* at the small end, the sides of the taper if extended will meet at a point on the center line at some distance *L*. These

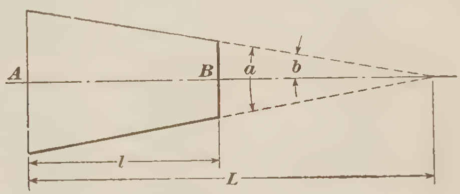


FIG. 48

two sides form an angle *a*, called the included angle, between them. Half the included angle, or angle *b*, is called the *angle with the center line*, and it is this angle to which the taper attachment bar on a lathe must be set in order to turn the given taper.

EXAMPLE.—If a piece of turned work has a taper of ½ inch per foot, what is its included angle?

SOLUTION.—Referring to Table VII, locate ½ inch in the first column, and opposite this taper read 2° 23′ as the required angle.

66. When it is desired to calculate the angle with the center line without the use of Table VII, use the following rule:

Rule.—*Divide the taper per foot by 24 and find the angle corresponding to this tangent. To get the included angle double the center-line angle.*

EXAMPLE.—What is the center-line angle of a turned tapered piece having a taper of $\frac{3}{4}$ inch per foot?

SOLUTION.—Tangent of center-line angle equals $\frac{3}{4} \div 24 = \frac{1}{32} = .03125$, corresponding to 1° 47′ 22″. (NOTE.—The table of tangents will be found in the lesson, *Use of Trigonometric Table.*) Twice the center-line angle, or 3° 34′ 44″, is the included angle.

67. When the included angle of the taper is given and the taper per foot is wanted, use the following rule:

Rule.—*Divide the angle by 2 and find its tangent from a table of tangents. Then multiply this tangent by 24.*

EXAMPLE.—A piece of turned work has an included angle of 3° 34′ 44″. What is its taper per foot?

SOLUTION.—Half the angle is 1° 47′ 22″, and its tangent is .03125, and this multiplied by $24 = .75 = \frac{3}{4}$ inch per foot.

68. Other Problems.—Often it is desired to find the taper per foot when the large and small diameters of the work, and the length of taper in inches are known.

Rule.—*To find the taper per foot when the two diameters and length of taper in inches are known, subtract the small diameter from the large one, divide by the length of the taper, and multiply by 12.*

EXAMPLE.—A piece of work 16 inches long is tapered over its whole length. If the large end is 9 inches in diameter and the small end $8\frac{1}{2}$ inches, what is the taper per foot?

SOLUTION.—Applying the rule: $9 - 8\frac{1}{2} = \frac{1}{2}$ inch, and $\frac{\frac{1}{2}}{16} = \frac{1}{32}$. The taper per foot is thus $\frac{1}{32} \times 12 = \frac{12}{32} = \frac{3}{8}$ inch. Ans.

69. When the taper per foot is known and it is required to find the taper in any given length of the piece, the following rule may be used:

Rule.—*To find the taper in any given length in inches when the taper per foot is known, divide the taper per foot by 12, and multiply by the length of the tapered part.*

EXAMPLE.—If a piece of work is tapered over 9 inches of the length and the taper is $\frac{3}{4}$ inch per foot, what is the taper on the tapered part?

SOLUTION.—According to the rule: $\frac{\frac{3}{4}}{12} = \frac{1}{16}$ = the taper per inch. The amount of taper is thus: $\frac{1}{16} \times 9 = \frac{9}{16}$ inch. Ans.

This problem may also be solved without the use of any calculations, by applying the values in Table VIII. According to the Table, for a length of 9 inches and a taper of $\frac{3}{4}$ inch per foot, the taper is .5625 inch, or $\frac{9}{16}$ inch.

TABLE VIII

TAPER IN CERTAIN LENGTH, WHEN TAPER PER FOOT IS GIVEN

Length of Tapered Portion	Taper per Foot, in Inches									
	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{4}$
$\frac{1}{32}$	.0002	.0002	.0003	.0007	.0010	.0013	.0016	.0020	.0026	.0033
$\frac{1}{16}$	.0003	.0005	.0007	.0013	.0020	.0026	.0033	.0039	.0052	.0065
$\frac{1}{8}$	.0007	.0010	.0013	.0026	.0039	.0052	.0065	.0078	.0104	.0130
$\frac{3}{16}$	.0010	.0015	.0020	.0039	.0059	.0078	.0098	.0117	.0156	.0195
$\frac{1}{4}$	.0013	.0020	.0026	.0052	.0078	.0104	.0130	.0156	.0208	.0260
$\frac{5}{16}$	.0016	.0024	.0033	.0065	.0098	.0130	.0163	.0195	.0260	.0326
$\frac{3}{8}$	.0020	.0029	.0039	.0078	.0117	.0156	.0195	.0234	.0312	.0391
$\frac{7}{16}$	.0023	.0034	.0046	.0091	.0137	.0182	.0228	.0273	.0365	.0456
$\frac{1}{2}$	.0026	.0039	.0052	.0104	.0156	.0208	.0260	.0312	.0417	.0521
$\frac{9}{16}$	.0029	.0044	.0059	.0117	.0176	.0234	.0293	.0352	.0469	.0586
$\frac{5}{8}$	.0033	.0049	.0065	.0130	.0195	.0260	.0326	.0391	.0521	.0651
$\frac{11}{16}$	.0036	.0054	.0072	.0143	.0215	.0286	.0358	.0430	.0573	.0716
$\frac{3}{4}$	.0039	.0059	.0078	.0156	.0234	.0312	.0391	.0469	.0625	.0781
$\frac{13}{16}$	.0042	.0063	.0085	.0169	.0254	.0339	.0423	.0508	.0677	.0846
$\frac{7}{8}$	.0046	.0068	.0091	.0182	.0273	.0365	.0456	.0547	.0729	.0911
$\frac{15}{16}$	.0049	.0073	.0098	.0195	.0293	.0391	.0488	.0586	.0781	.0977
1	.0052	.0078	.0104	.0208	.0312	.0417	.0521	.0625	.0833	.1042
2	.0104	.0156	.0208	.0417	.0625	.0833	.1042	.125	.1667	.2083
3	.0156	.0234	.0312	.0625	.0937	.1250	.1562	.1875	.250	.3125
4	.0208	.0312	.0417	.0833	.125	.1667	.2083	.250	.3333	.4167
5	.0260	.0391	.0521	.1042	.1562	.2083	.2604	.3125	.4167	.5208
6	.0312	.0469	.0625	.125	.1875	.250	.3125	.375	.500	.625
7	.0365	.0547	.0729	.1458	.2187	.2917	.3646	.4375	.5833	.7292
8	.0417	.0625	.0833	.1667	.250	.3333	.4167	.500	.6667	.8333
9	.0469	.0703	.0937	.1875	.2812	.375	.4687	.5625	.750	.9375
10	.0521	.0781	.1042	.2083	.3125	.4167	.5208	.625	.8333	1.0417
11	.0573	.0859	.1146	.2292	.3437	.4583	.5729	.6875	.9167	1.1458
12	.0625	.0937	.125	.250	.375	.500	.625	.750	1.000	1.250
13	.0677	.1016	.1354	.2708	.4062	.5417	.6771	.8125	1.0833	1.3542
14	.0729	.1094	.1458	.2917	.4375	.5833	.7292	.875	1.1667	1.4583
15	.0781	.1172	.1562	.3125	.4687	.625	.7812	.9375	1.250	1.5625
16	.0833	.125	.1667	.3333	.500	.6667	.8333	1.000	1.3333	1.6667
17	.0885	.1328	.1771	.3542	.5312	.7083	.8854	1.0625	1.4167	1.7708
18	.0937	.1406	.1875	.3750	.5625	.750	.9375	1.125	1.500	1.875
19	.0990	.1484	.1979	.3958	.5937	.7917	.9896	1.1875	1.5833	1.9792
20	.1042	.1562	.2083	.4167	.625	.8333	1.0417	1.250	1.6667	2.0833
21	.1094	.1641	.2187	.4375	.6562	.875	1.0937	1.3125	1.750	2.1875
22	.1146	.1719	.2292	.4583	.6875	.9167	1.1458	1.375	1.8333	2.2917
23	.1198	.1797	.2396	.4792	.7187	.9583	1.1979	1.4375	1.9167	2.3958
24	.125	.1875	.250	.500	.750	1.000	1.250	1.500	2.000	2.500

70. The following rules apply when it is desired to find the diameter of one end of the tapered portion of the work when the diameter of the other end, the length of the taper, and the taper per foot are known:

Rule.—*To find the large diameter in inches when the small diameter in inches, length of taper in inches, and the taper per foot are known, divide the taper per foot by 12, multiply by the length of taper, and add the result to the small diameter.*

Rule.—*To find the small diameter in inches when the large diameter in inches, length of taper in inches, and the taper per foot are known, divide the taper per foot by 12, multiply by the length of taper, and subtract the result from the large diameter.*

EXAMPLE.—The large diameter of a piece of work, tapered $\frac{3}{8}$ inch per foot, is 5 inches. If the piece is 16 inches long, what is the diameter at the small end?

SOLUTION.—Applying the rule: $\frac{\frac{3}{8}}{12}=\frac{3}{96}$, and $\frac{3}{96}\times 16=\frac{48}{96}=\frac{1}{2}$ inch. The small diameter is, therefore, $5-\frac{1}{2}=4\frac{1}{2}$ inches. Ans.

EXAMPLE.—A piece of work 6 inches long is tapered $\frac{1}{2}$ inch per foot. If the diameter at the small end is 7 inches, what is the large diameter?

SOLUTION.—Applying the rule: $\frac{\frac{1}{2}}{12}=\frac{1}{24}$, and $\frac{1}{24}\times 6=\frac{1}{4}$ inch. The large diameter is thus $7+\frac{1}{4}=7\frac{1}{4}$ inches. Ans.

METHODS OF TURNING TAPERS

71. Methods Used.—There are four common ways by which a taper may be turned. The dead center may be set out of line with the live center; a lathe provided with a special taper attachment may be used; a special turning lathe in which the headstock and tailstock may be set at an angle to the line of tool feed-motion may be employed; or the taper may be turned with the aid of a compound rest.

72. Setting Over the Tailstock.—In Fig. 49 is shown the method of measuring the distance that the tailstock center *a* is set out of line with the headstock center *b*. The tailstock is moved close to the headstock and a scale placed edgewise against

the two points from underneath. This set-over is the depth of the cut on the small end of the taper, and the approximate reduction in diameter of the small end of the taper will be twice the set-over.

The construction of the tailstock for taper turning is shown in Fig. 50. The base *a* fits on the **V**'s of the lathe bed and this may

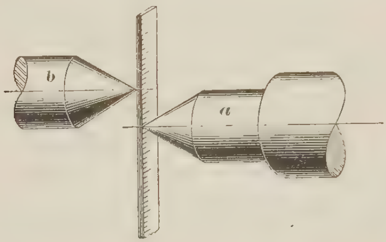


FIG. 49

be moved lengthwise of the bed. The body *b* fits the top of the base, and is lined square across the lathe by a groove and a tongue *c*. A screw *d* at the front and a similar one at the back are used to give the crosswise adjustment. The body is clamped to the base by the nut and bolt *e*. Some tailstocks have a center line *f* and a scale to indicate the position of the body *b* on the base *a*.

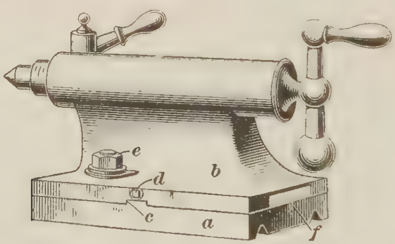


FIG. 50

73. Calculating Amount of Tailstock Set-Over.—The amount that a center should be moved to turn a given taper can be easily calculated. Suppose that it is desired to turn a taper $\frac{1}{2}$ inch to the foot on the piece shown in Fig. 51. This means that in 1 foot of length the difference of diameters is $\frac{1}{2}$ inch, and as the piece is 1 foot long, it will be necessary to move the dead

center out of line and toward the front of the machine one-half of this half inch, or $\frac{1}{4}$ inch. It must be understood in turning that if a cut $\frac{1}{4}$ inch deep is taken the diameter is reduced $\frac{1}{2}$ inch.

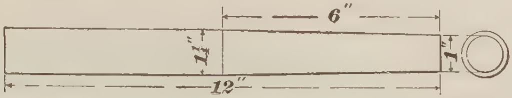


Fig. 51

Moving the dead center toward the tool $\frac{1}{4}$ inch is equivalent to taking a shaving, or cut, $\frac{1}{4}$ inch deep.

74. The general rule for calculating the amount of set-over is as follows:

Rule.—*Divide the taper in inches per foot by 12 to reduce to taper in inches per inch. Then multiply by the total length of*

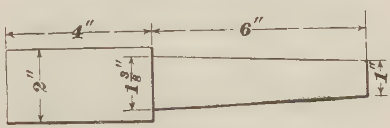


Fig. 52

the piece in inches and divide by 2. The quotient will be the set-over.

Example.—Suppose the piece shown in Fig. 52 is 10 inches long and it is to be tapered $\frac{3}{4}$ inch per foot on 6 inches of one end, what should be the set-over of the tail center?

Solution.—Applying the rule, the set-over is $(\frac{3}{4}\div 12)\times 10\div 2=\frac{1}{16}\times\frac{10}{2}=\frac{10}{32}=\frac{5}{16}$ inch. Ans.

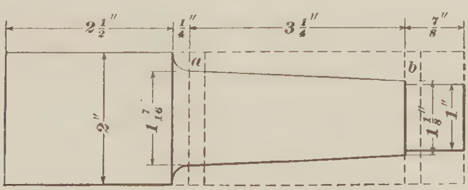


Fig. 53

75. Setting Tail Center by Notches.—When the taper per foot is not given but the diameters and the distance between them are known, the notch method may be used. Suppose that a taper as shown in Fig. 53 is to be turned. Notches are first

cut in the stock, as shown at *a* and *b*. One notch *b* is cut to the diameter of the taper at the small end. The second notch *a* is cut to the correct diameter at the large end. From these diameters, measurements are taken for setting the lathe.

76. The work is kept between the centers after notching and the tool held in the tool post, the same as for cutting the notches. The dead center is moved toward the front about ¼ inch. The tool is then moved opposite one notch of the work, as at *a*, Fig. 54, and the distance from the point of the tool to the bottom of the notch is measured. The tool and carriage are then moved opposite the second notch *b*, and the same measurement is taken. If the measurements are alike, the work is correctly set; if not, the dead center must be adjusted until they are the same. After each adjustment of the tailstock, the distance must be measured from each notch to the tool point. It is not right to measure with the tool in position *a*, and then adjust the tailstock until the measurement at *b* is the same, for it will be seen that in changing the measurement at *b* the measurement at *a* will also change, although not so rapidly.

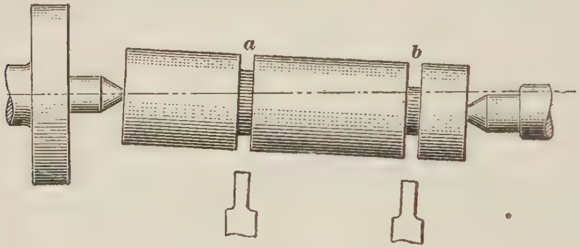


Fig. 54

77. Measuring Distance From Work to Point of Tool. Various methods are employed for taking the measurements from the work to the point of the tool. A steel scale or a pair of inside calipers may be employed. The scale is held edgewise against the bottom of the notch and the point of the tool brought up against the outer edge. When calipers are used, it is better to use the butt end of the tool, or some flat surface, as it is easier to measure between surfaces than between points.

When close measurements are desired, the tool, or, better, some article with a rounded end, is brought close to the model, and at the height of the center, so that it loosely pinches a piece of tissue paper. The tool and the paper are moved along the length of the taper and the setting is tested at various places by pulling the paper. If the paper slips between the tool and the taper model with about the same pull at all places, the setting is correct.

78. Universal Dial Indicator for Testing Tapers.—The universal dial indicator illustrated in the lesson on *Measuring Instruments* may be used to test the setting of tapered work. When used, for instance, for testing the taper of the live center it is customary to set it with the shank held in the tool post in place of the ordinary lathe tool, and with the ball point on a level with the lathe centers, and in touch with the cone point of the center. Then the headstock spindle is rotated slowly by hand and the dial noted. If the live center does not rotate truly concentric with its axis, the dial will show the error. The center should in that case be reground.

79. Setting Tailstock With a Model Taper.—When a model taper has been furnished, the tailstock may be set directly from it. The model is put between the lathe centers, and the dead center is so adjusted that the measurements from the point of a tool in the tool post to the taper model remain constant as the carriage and tool are moved along its length. The measurements may be made by any of the methods that have been described.

80. Wear of Centers When Dead Center Has Been Set Over.—When the dead center is set over considerably, as shown in Fig. 55, it will be seen that the dead center touches the work at only two points. This is obectionable, as the work rotates about the dead center, and there is a tendency to wear away both the center holes and the lathe centers. Much wear would result in a shape as shown in Fig. 56. The front side of the point of the center is worn away, a groove is formed at the back, and the center hole is worn into a bell shape. The

live center revolves with the work, so that the wearing action between it and the center is somewhat different. On the dead center the work has a rotating motion, but on the live center it has a reciprocating motion. The result is that the live center

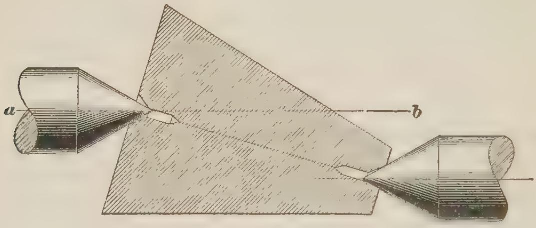


FIG. 55

is worn evenly all around, and the center hole is worn to about the same shape as the dead-center hole.

81. If a part of the work has been turned true and parallel, it will be found to run untrue on the worn center holes. After a taper has been turned, the tapered part and the parallel part will not run true with each other. Besides, if the lathe centers become much worn, it will be necessary to grind them before parallel or true work can again be turned. Moreover, it is uncertain just what the effective length of the piece of tapered work may be. The total length of the piece is taken when figuring the amount of set-over for a given taper but the effective length must be part way in the center holes somewhere between where the point of the center reaches and where the end of the work bears on the center.

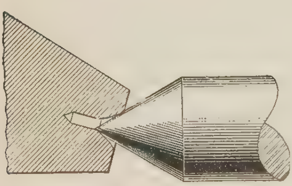


FIG. 56

82. Different Tapers for Different Lengths of Work. When it is desired to turn the same taper on a number of pieces of different lengths, it will be found that the center must be adjusted or reset for each length of work. When the lathe is adjusted to turn a given taper, or work of a particular length, it will be found that if the work is a little longer or shorter, the

taper will be changed. Suppose that, in Fig. 57, *a b* represents the line of lathe centers for turning parallel work. Assume that the dead center is set out of line $\frac{1}{4}$ inch, as shown by the line *c d*. Any piece that may be turned with the dead center thus set will have a difference between diameters at its ends of approximately $\frac{1}{2}$ inch, for the set-over is measured on the line *h* at right angles to the center line *a b* and the taper line *j k*. On the other hand, the diameter of the taper at the small end is measured on the line *i*, which is longer than *h*. Therefore, the cut removes more than its depth from the radius *i* of the work.

83. If the piece is 1 inch long, so that the dead center is in position *e*, the taper will be $\frac{1}{2}$ inch to the inch. If the piece is 2 inches long, so that the dead center is in position *f*, the taper will be $\frac{1}{2}$ inch to 2 inches, or $\frac{1}{4}$ inch to the inch. If the piece is 3 inches long, so that the dead center is in position *g*, the taper will be $\frac{1}{2}$ inch to 3 inches, or 2 inches to the foot. These three tapers may be compared by reference to the

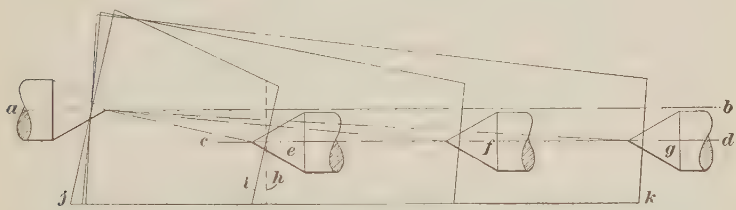


FIG. 57

outlines. It is evident that any slight difference in the distances between centers in turning two pieces of work will make a difference of taper that can readily be detected when fitting work. If in two pieces of the same length, one has much deeper center holes than the other, it will allow the lathe centers to come closer together, which will cause a slight error in the taper that may have to be corrected in the final fitting.

84. Limit of Tailstock Set-Over.—The amount of taper that can be turned between centers by setting over the center is limited by the total length of work and the amount of adjustment possible in the tailstock. Suppose the greatest amount of

set-over in the tailstock is 2 inches. This will make a difference of diameter at the ends of the work of 4 inches. If it is desired to turn a taper of 1 inch to the foot, the greatest length of shaft on which it could be turned is 4 feet, and if the shaft or work should be longer, it would be necessary to use some other method of turning the taper.

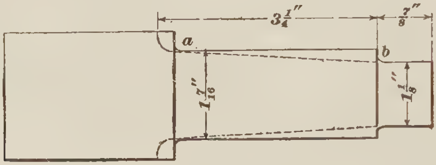


FIG. 58

85. Setting Tailstock for Tapers by Turning Parallel to Two Diameters.—Sometimes tapered work is set by turning to two diameters, as shown in Fig. 58, the work being turned to the smallest diameter of the taper up to its beginning, and then from this point to the head of the taper the work is turned to the largest diameter of the taper, as shown. After this, the tool may be set to the large and small diameters *a* and *b*, as in the case of setting by notches. The advantage of this method is that a large portion of the stock is removed while the work is between centers that are in line and the centers of the work fit perfectly.

86. Turning and Testing Work Tapered by Set-Over Method.—As all methods of calculation and measurement

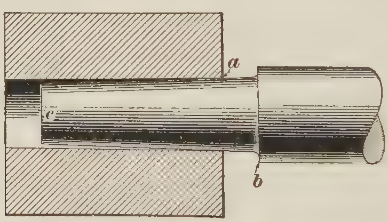


FIG. 59

made to determine the distance to set the tail center over to turn a given taper give only approximate results, the operator must make trial roughing cuts and tests of the taper. After the roughing cut has been taken, and before the tapered piece is near

the finished size, it should be tested in the piece it is intended to fit. The taper is carefully placed in the tapered hole and first tested by the sense of feeling. If one end is much too small, as at *c*, Fig. 59, it can be detected by rocking the work in the hole. The plug will just fill the hole at the outer end *a*, and though the imperfect fit cannot be seen, it can easily be felt.

87. In case the indications are that the dead center was moved too far out of line, it should be moved back a very slight amount and another cut taken over the work. After this cut, the work should be tested again, and if there is no perceptible wabble the fit may be tested still more closely by drawing three chalk lines along its length. The work is then placed in the hole and a turn or two given in a direction opposite to the motion it had in the lathe. On removing the work, it will be seen that the chalk has rubbed off, and is black at either one end or the other, depending on which end was too large.

88. The tailstock is adjusted again, and a light cut is taken over the taper. The chalk marks are drawn along the taper and it is tried in the hole again. If the chalk is rubbed off evenly the whole length it indicates that the setting is correct. The taper is then turned to size by one or more light cuts. The size should be such that the taper will go in nearly as far as required. The lathe is speeded up and the taper is filed evenly all over with a smooth file to remove the tool marks. Chalk marks are made along it again and it is tried in the hole by giving it a turn or two backwards. The chalk will be rubbed off the high parts of the taper, and a smooth or a dead-smooth file should be employed to touch off these high spots. The file should be clean and used with a light, even pressure. A further test will usually show that the bearing has been improved. The tests and corrections are repeated until the chalk is rubbed off evenly the whole length, when the taper will be a practical fit. For production work grinding is the common method instead of filing.

89. Prussian-Blue Marking.—In fine fitting, the thickness of a chalk line is sufficient to make an error of some importance,

so a substitute is used. One-half of the tapered piece along its length is coated very thinly with Prussian-blue marking, applied with the finger, and nearly all rubbed off, just enough being left to give it color. The work is then tested in the hole or gauge, and a turn given to it. If the marking is evenly distributed along the taper, it indicates a perfect bearing.

90. Height of Tool to Turn Tapers.—In setting a tool for turning a taper, it is very important that the point of the tool should be at the same height as the axis of the work. This fixed height of tool applies to all methods of turning tapers. Since the position of the tool is fixed at a given height, its keen-

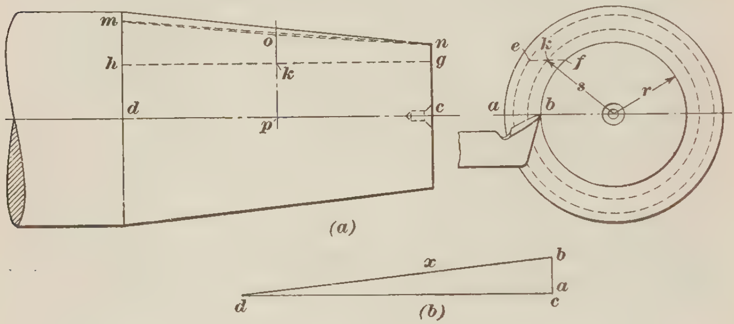


FIG. 60

ness must be given by grinding the top face with considerable back and side slope, or rake, as shown in Fig. 60. Its front edge need have very little clearance.

91. If the tool be set above the centers, it will turn the taper too small at the large end, and the tapered surface will be curved instead of straight from end to end. Suppose that a taper has been turned, as shown by the full lines in Fig. 60 (*a*), with the tool correctly set at the center. The lines *a b* and *c d* represent the paths of the tool while it actually is following the slope line of the taper. The tool recedes a distance *a b* from the center of the work, and moves along the lathe a distance *c d*. These two movements form a right-angled triangle, as shown at (*b*). With a base line equal to *c d* and a height of *a b*, the slope line *x*, or *hypotenuse*, gives the actual, or resulting, tool

movement. With the machine once set, the tool will travel this slope line over and over regardless of the height of the tool.

92. Next, suppose that the tool is set above the center, as at *f*, and adjusted to cut the small end of the taper with a radius *r* as before. The path of the tool will then be *f e*, equal to *a b*, and *g h* equal to *c d*. The dotted circle drawn through *e* shows the diameter turned on the large end of the taper under these conditions. This diameter is smaller than the original one, and the higher the tool is set the greater the error.

In addition to being smaller at the large end, the slope of the taper will not be a straight line, as *m n*, but it will be curved inward from the true taper. This curve may be drawn by marking the diameters of the taper on the side views as taken from the end view, Fig. 60 (*a*).

93. As an example, take the point *k*, at the middle of *e f* in the end view and draw the circle with the radius *s* showing the size of the taper at the middle of its length. Likewise, locate the point *k* at the middle of *g h* in the side view and lay off the distance *s* from the center line *c d*, or $p\ o = s$. This will locate the point *o* on the circumference of the taper at its mid-length. The curve *m o n* indicates the curve turned on the taper when the tool is set above the center at *f*.

94. Additional points of this curve may be laid off, in a similar way as shown for *o*, by taking other proportions of the lines *e f* and *g h*. Therefore, a true taper will not be turned when the tool is set high, and where a plug must be turned to fit a tapered hole with precision, as in valve construction, close attention must be given to the tool setting. It should be noted, however, that where the tapered plug is turned and the hole bored with the tool set at the same height for each operation, the two parts will fit together exactly, although they will not be truly conical.

95. Turning Tapers With Taper Attachment.—In order to overcome the many objections of the set-over method of taper turning, the taper attachment for engine lathes is commonly used. One form of taper attachment is shown on the rear of

the lathe in Fig. 61. The lathe centers are in line and the taper is turned by moving the tool crosswise of the lathe a distance equal to half the taper. A bar *a* with a tongue on top and parallel to the **V**'s of the lathe bed is bolted to a bracket on the back of the saddle *b*. A long slide *c* fits over the tongue on *a*, and may be moved lengthwise.

96. One end of the slide *c* may be attached to the back **V** at any point by means of the clamp *d*. A long screw *e* and two hand nuts *f* serve to give special adjustment of the slide *c* after

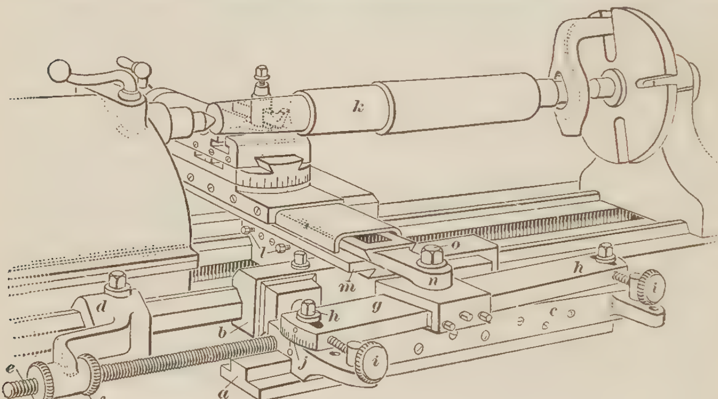


FIG. 61

the clamp *d* is set. A parallel bar *g* is pivoted at its center on top of the slide *c*, and there are two clamp bolts *h*, one through a slot in each end, to hold it in any desired position on *c*. The bar *g* may be set parallel to the lathe **V**'s, or so that it will stand at an angle to them.

The position of the bar *g* is adjusted by means of a hand screw *i* at each end. Zero lines *j* on the end of the bar *g* and the slide *c* indicate the location of *g* when parallel to the lathe **V**'s. The scale at *j* is usually graduated to indicate inches per foot taper on the work *k*. Sometimes the graduations indicate degrees of taper, and occasionally both inches per foot and degrees are given on the scale.

97. Operation of Taper Attachment.—When the taper attachment is to be used, the bar *a*, Fig. 61, and slide *g* are set

opposite the part k of the work to be tapered. Then the two binder screws l are loosened to allow the lower cross-slide m to move. Next the extension n of m is attached by means of the pivot bolt o to the sliding block that fits over the taper bar g. The cross-slide m will then move across the lathe a distance corresponding to the slope of the taper bar g while it moves along the lathe bed with the carriage. The tool is adjusted to the work by means of the cross-feed screw or the compound rest.

98. Setting of Taper Attachment.—Suppose the guide bar to be 2 feet long. It is pivoted at the center, so that if the bar is turned at such an angle that the ends are out of line with each other $\frac{1}{4}$ inch, and the carriage is moved along from the center of the bar to the end, then the part n and the tool will be moved across the lathe bed $\frac{1}{8}$ inch. This is equivalent to setting over the tailstock $\frac{1}{8}$ inch, which on a piece 1 foot long would turn a taper of $\frac{1}{4}$ inch to the foot. If the carriage moved the whole length of the bar, or 2 feet, the tool would move across the lathe bed $\frac{1}{4}$ inch, which would give a taper of $\frac{1}{2}$ inch in 2 feet, or $\frac{1}{4}$ inch to the foot, the same as before. It will be seen from this that when the attachment is once set it will turn the same taper on pieces of any length.

99. Some taper attachments do not have the lower cross-slide m, Fig. 61. In these the tool slide may be connected to the sliding block, and when this is done the nut on the cross-feed screw must be disconnected from the screw, thus allowing the cross-movement of the tool to be controlled entirely by the taper bar. Then it is necessary to have a compound rest with its feed-screw to adjust the tool to the work.

100. Taper Turning by Use of Compound Rest.—When the taper is very abrupt, such as 1 inch or more to the inch, it can be turned best by means of the compound rest. The base of the compound rest is usually graduated in degrees, so that it may easily be set at the angle of the taper. The tool is then fed along the surface of the taper by means of the feed-screw of the compound rest, as shown in Fig. 62. Before too much

metal is turned off, the accuracy of the tool setting and of the taper of the work should be tested, as shown in Fig. 63. The

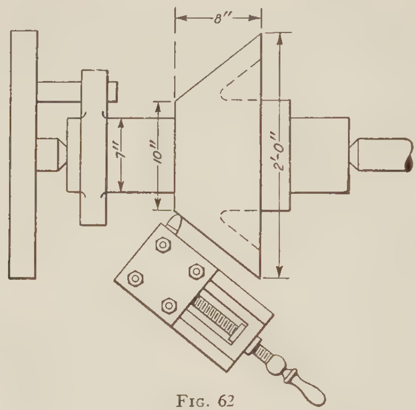


FIG. 62

stock, or beam, *a* of a bevel or a universal protractor set to the correct angle is placed against the face plate *b* and the tool support or the tapered surface is brought against the blade *c*.

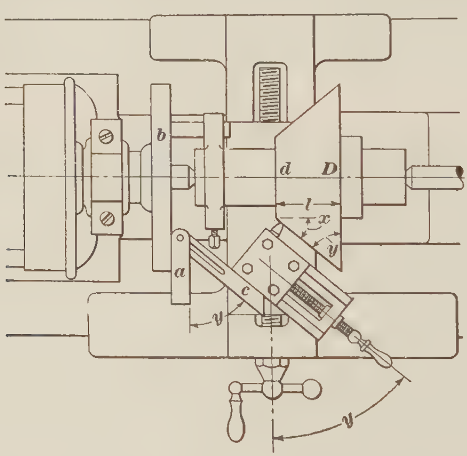


FIG. 63

101. Layout of Angle for Compound Rest.—If the angle is not given on the drawing, then it may be found from the dimensions of the work, as in Fig. 64. Draw two lines *a b*

and $c\ d$ at right angles to each other and intersecting at o, as in Fig. 59. On $a\ b$ lay off $o\ e$ equal to 8 inches, which is the length of the taper in Fig. 63. On $c\ d$ lay off $o\ f$ equal to 7 inches, which is equal to the taper on one side of the work $(24-10)\div 2=7$, or half the difference between the two diameters. The sloping line $e\ f$ will be that of the taper on one side. Then set the bevel protractor to the angle y and line the feed-screw of the compound rest to the same angle, as shown in Fig. 63.

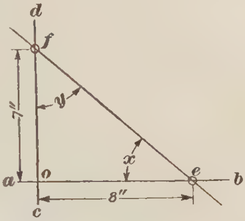


FIG. 64

102. Computing Taper Angle for Compound Rest. Instead of laying out the taper angle as in Fig. 64, it may be computed as follows: Referring to Fig. 63, let l be the length of the taper, D its large diameter, and d its small one. Then tan of angle x, which is the angle of the taper with the center line as previously explained, is $\frac{D-d}{2\,l}$. Also, angle $y=90°-x$, or $\tan y=\frac{2\,l}{D-d}$.

EXAMPLE.—In Fig. 63 the taper length is 8 inches, D is 24 inches, and d is 10 inches. What is the angle y to set the compound rest?

SOLUTION.—Tan $y=\frac{2\,l}{D-d}=\frac{2\times 8}{24-10}=\frac{16}{14}=1.14285$, corresponding to an angle of 48° 48′ 50″. Angle $x=90°-y$, or 41° 11′ 10″. Ans.

103. Turning Tapers by Use of Two Feed-Motions.—A method of roughing steep tapers rapidly with the compound rest is to use the two feeds at once. While the longitudinal feed is operated by power or by one hand, the tool is fed crosswise by the other hand. When the two feeds have the proper rates, the tool will move along the general direction of the required taper.

LATHE FITTING

CLASSIFICATION OF FITS

USES OF FITS

104. Definition.—In lathe work, the term *fitting* implies the turning of a piece to a diameter that will be either slightly larger or smaller than the hole that it is to enter. It also applies to the boring of a hole so that its diameter will be slightly larger or smaller than that of the entering piece. The turning or boring operations are similar to those for general work, but the lathe operator must consider the fitting allowances and be able to finish the work to close measurements.

105. Fits Used in Machine Construction.—There are five kinds of fits used in machine construction: The *running,* or *sliding, fit;* the *wringing,* or *push, fit;* the *driving fit;* the *press,* or *forced, fit;* and the *shrinkage fit.* The first is used for parts that turn or slide on one another, such as shafts and spindles in their bearings, where there must be enough room between them for a film of lubricant. The wringing fit is employed for parts that must lie one within the other, without adjustment, and where the size must be maintained, as, for example, in plug gauges and the dead spindles of lathes. The last three kinds are used when the parts are to be put tightly together and must remain so.

SLIDING OR RUNNING FITS

106. Requirements for Running Fits.—The most nearly perfect sliding or running cylindrical fits are those whose surfaces most nearly approach perfect cylinders. There must be sufficient difference in diameter to allow the shaft to revolve

freely and to admit oil for lubricating. If the shaft and bearing were of exactly the same diameter, the shaft might be turned in the bearing so long as it was kept slightly in motion; but when it stopped, it would be very difficult to start it again. With such perfect fits, the heat generated by the revolving shaft would cause it to expand so that it would be larger than the bearing, and thus grip the parts together.

107. Allowance for Running Fits.—The closeness allowed for cylindrical running fits depends on the diameter of the shaft, and the length of hole, and the condition of the surfaces. Greater differences in diameter are allowed for large shafts than for small ones. In some small machines, spindles about $\frac{1}{4}$ inch in diameter will require not over .0005 inch difference in diameter, whereas a shaft 12 inches in diameter would require from .005 to .01 inch or more.

108. Making Running Fits.—To make a good fit, the surface should be smooth and true. If the hole or bearing is finished by boring, the tool should be made to take a very smooth cut. If there is danger that the work is sprung by chucking, the pressure should be relieved as much as possible before the finishing cut is made. The work should be tested to determine whether it is round and the sides parallel. Whenever possible, it is best to finish holes by reaming, as it tends to make the holes of a standard size and the walls of the holes smooth and parallel. When a running fit is being made, it is best to finish the bearing first, as it is easier to fit the shaft to the hole than to bore the hole to fit the shaft. When gauges are at hand, the cut-and-try method is not used, as the holes are all reamed to pass the limit gauge and the shaft also is turned within limits, so that the pieces will fit each other with sufficient accuracy.

109. Standard or limit gauges are not always used, especially when but a few pieces of a size are to be fitted. In this case, the hole that has been finished must act as the gauge for the shaft. The closeness of the fit depends greatly, as before stated, on the smoothness of the surfaces. The bearing may

have been reamed, but the shaft finished with an ordinary finishing cut, so that the bearing touches only on the points of the tool marks. If such a fit were allowed to pass, the pressure would come on the points of the tool marks and cause them to wear away rapidly. Furthermore, because of the spiral threads or tool marks around the work, it would be difficult to keep the bearing lubricated, the spiral thread tending to drive the oil out of one end or the other of the bearing, depending on the direction of rotation of the shaft. Because of a lack of oil and the narrow bearing points, such a fit would soon wear loose. This same wearing action would also take place if the shaft were smooth and true, but the bore left rough with tool marks.

110. The sliding, or running, fit is made by first finding the correct size of the hole at both ends. This can be done either by calipering or by trying a solid mandrel in the hole from each end. The calipers are then set to the size of the mandrel at the large end of the hole and a finishing cut is started. When this cut has run from $\frac{1}{8}$ to $\frac{1}{4}$ inch along the shaft, the feed is thrown out and the work is tried in the large end of the hole. If the work will just twist in, the size is right and the cut can be taken as far as required. The surface is then filed carefully with a smooth or dead-smooth file at a speed fast enough to have the work make several turns to each stroke of the file, but not fast enough to burn the file. The tool marks are filed evenly from one end to the other and the piece is oiled and tried in the hole. It is assumed that on this trial the piece wrings clear through the hole and that on removing it there are tight bearing marks in a number of places. The work is replaced in the lathe, the bearing marks touched off by careful filing, and the work polished lightly by repeatedly moving a strip of No. 60 emery cloth from end to end. After being carefully wiped clean of emery, it is oiled and tried in the hole. If it turns easily without shaking, it is a good, close fit.

111. Fitting and Finishing by Grinding.—Much work formerly fitted and finished on the lathe is now finished on the

grinder. Lathe work that is to be finished on the grinder is centered in the usual way. The ends and all shoulders are squared to the required lengths, and roughing cuts are made over all cylindrical and tapered surfaces. These roughing cuts may be made at high speed, and with feeds as coarse as the work will stand without excessive springing and chattering. The greatest amount of stock should be removed in the shortest time, and from .010 to .025 inch in diameter should be left for the grinder to remove in finishing.

DRIVING FITS

112. Requirements for Driving Fits.—In a driving fit the plug or shaft is made slightly larger in diameter than the hole in the surrounding piece, and they are assembled by driving the shaft, or pin, into the hole. This method is used when the two pieces are intended to keep fixed positions in relation to each other.

113. Allowances for Driving Fits.—The allowance, or difference in diameter, for driving fits depends on the diameter of the work, the length of the hole, the condition of the surfaces, and the strength of the enveloping piece. If the hole is long, less difference in diameter is required than when the hole is short. When the hole and the shaft are finished smooth, a very slight difference in diameter makes a great difference in the closeness of fit. If the surfaces are rough, a much greater difference in diameter is allowable. When the surfaces are smooth, a difference of from .0005 to .001 inch for each inch in diameter will make a very tight fit. Where the surfaces are rough, a difference of .002 or .003 inch per inch will be necessary. The roughness of the surfaces will be worn down as they are driven over each other.

114. Making a Driving Fit.—The size of the hole to be fitted is first determined. If a solid mandrel is available it may be driven into the hole and calipered at the large end. The surface to be fitted is then turned to the size of the mandrel plus the allowance called for by the tightness with which the

parts are to fit. If a mandrel cannot be used, an inside caliper or an end measure, often called a pin gauge, is employed for setting the outside caliper. The surface is filed to remove the tool marks, and the parts are ready to be assembled.

115. Assembling a Driving Fit.—When putting a driving fit together, the surfaces should be oiled. The piece into which the shaft is to be driven should be set on a firm foundation, and the shaft carefully entered and driven to place with a hammer or sledge. Care should be taken not to bruise the work when driving it; consequently, a block of wood, lead, or Babbitt is used to strike on. Sometimes the work is so shaped and in such position that a ram can be rigged for driving the pieces together. This ram consists of a beam or a round iron bar supported from above by ropes or chains so that it hangs in a horizontal position, level with the work. The ram is drawn back and then pushed forwards so that its end strikes against the work. This is a very effective way of driving. If the work is large and the fit is very close, the driving may be helped by using clamps and bolts, which can be arranged to assist in drawing or forcing the pieces together. With the combined forces of the bolts and the ram, the shaft can be driven to place.

PRESS FITS

116. Requirements for Press Fits.—A press fit is one in which the internal part is made so much greater in diameter than the hole it enters that some form of press is required to squeeze the internal part into position. It is also called a *force fit*. The allowance for a press fit is about double that required for a driving fit. The forcing method is used for work too large to be driven together conveniently. This method is also employed for putting engine cranks on shafts, for inserting crankpins in the cranks, and for a great variety of similar work. It is probably used most extensively for putting the wheels on car axles.

117. Classification of Press Fits.—There are two general classes of press fits; namely, the *straight* and the *taper*. When

making a press fit the workman should inspect the hole thoroughly to ascertain the smoothness of its surface. He should then caliper it carefully in two or more directions at the entering end, to find whether it is round. He should caliper it also at the other end, to determine its roundness and to detect any taper. If these measurements vary, he should calculate a general average of them and to this average diameter add the allowance required for pressing. The process of turning and fitting the internal part does not differ materially from that used when making a drive fit.

118. Straight Press Fits.—The straight press fit is turned and fitted so that the entering end will just pass into the hole to form a guide for the parts. The necessary allowance is made and the shaft or part is tapered .001 inch to each inch of length of the bearing. This increase provides for the stretch of the hole and for the wear in the hole and on the entering part. If this allowance were not made the fit would not be so tight as intended. If the diameter and length of the bearing surfaces are excessive, less taper will suffice.

119. Taper Press Fits.—A better press fit, known as the taper press fit, is made when required. The hole is bored with a taper of about $\frac{1}{16}$ inch per foot and made as smooth and true as possible. A tapered cast-iron plug is then turned to the same size and taper, to be used as a surface plate for truing the hole. This is done by turning the piece in the hole to mark any high spots or irregularities. These are removed by scraping, and the process is repeated until the hole is true. The taper on the shaft is then turned in the exact position and to the taper specified by the designer, after which it is pushed into the hole to the point specified on the drawing. The advantages of the taper form are that less pressure is required in assembling, and the parts are more readily separated for renewal.

120. Allowances for Press Fits.—The allowance for press fits is more than for drive fits. The amount, however, depends on the materials used, the size of the hole, its length,

and the condition of the surfaces. It is the practice of some engine builders, who put cranks and crankpins together with press fits, to allow from .001 inch to .0025 inch difference for each inch of diameter. This requires a pressure of from 10 to 13 tons per inch of diameter, depending on the length of the hole, to force the pieces together. This pressure is estimated for diameters that range from 3 to 8 inches.

Car wheels and axles are required to go together within the limits of certain pressures. One railroad company's rule is that, for certain classes of wheels, the pressure required to force the wheel on to the axle shall not be less than 25 tons nor over 35 tons. On an axle 7 inches long and $4\frac{7}{8}$ inches in diameter, an allowance of about .007 inch is made. This requires a pressure of about 30 tons to press the wheel on.

121. Considerable skill is required by the workmen to make press fits; yet, after a little practice, they do it rapidly and can tell within a few tons the exact pressure required to force the wheel into place. In calipering the axles, the exact difference is not always measured by the workman. He may use a snap gauge that has been made sufficiently large to allow for the fit; or, if calipers are used, he may set them to the correct size and test the work so that a certain pressure is required to force the calipers over the work, experience having taught him how great this pressure should be.

SHRINKAGE FITS

122. Making a Shrinkage Fit.—A shrinkage fit is made by measuring the size of the hole accurately and calculating the shrinkage allowance that is required. The shrinkage allowance is about .001 inch per inch of diameter. The internal part is then turned so that it has the required allowance greater than the diameter of the hole. The parts are then assembled by heating the outer part to a red heat and sliding the internal piece into position. The heated part is then allowed to cool. If the internal piece, however, has been made first, as is often the case, the hole is bored enough smaller than the entering piece to provide the required allowance.

123. When the pieces are large, strong, and of suitable shapes, pressure may be used for putting them together without danger of bending or distorting them. On other classes of work there is no chance to drive or force the pieces together, as, for example, in putting the tires on locomotive wheels. For such large diameters, the difference of diameter in the fit would be so great that very powerful pressure would be required to start the tire on the wheel. By heating the tire, it expands sufficiently to let it drop over the wheel center with perfect freedom. The heated outer member is then cooled, causing it to grip the inner member with great pressure. Shrinkage fits are very often employed on small work in shops that have no press to put press fits together.

124. Allowance for Shrinkage Fits.—The amount of allowance for shrink fits is generally a little more than for press fits. A fair rule for small work is to allow about .003 inch for the first inch of diameter and to add .001 inch for each extra inch. The amount allowed for locomotive drivers varies, depending on the size of the wheel and the service. Most locomotive builders allow from .01 to .0125 inch to 1 foot of diameter.

125. Assembling Shrinkage Fits.—In assembling a shrink fit, the piece that has been bored is heated slightly and evenly. Ordinarily, a heat just sufficient to show a dull red is more than is required. Care should be taken that the piece is never hot enough to scale. The diameters should previously be tested so that there will be no danger that the pieces will not go together when one is heated. If too much allowance has been made, the pieces sometimes catch before the shaft is quite through to the desired place. Unless instantly removed, the shaft will bind so that it will be impossible to move in either way. The shaft begins to expand as soon as it enters the bored piece, and if the difference in diameter is slight at first, it will be very quickly made up by the rapid expansion of the shaft. Therefore, great speed is necessary in putting the pieces together when shrink fits are used, especially on small work. When the pieces are larger, such haste is not important.

126. In shrinking smaller pieces, as soon as the plug is in place, water should be applied to keep it cool. The enveloping piece must not be cooled too suddenly, or it is liable to crack, especially if it is cast iron. If a gear-wheel is being shrunk on a shaft and too much water is applied to the shaft and the hub of the wheel, there is danger that some of the arms will crack. If a cast-iron disk is being shrunk on a shaft and the circumference of the disk is rapidly cooled, there is danger that a radial crack will appear at the edge.

127. Shrinkage Fits in Large Guns.—There is probably no finer example of making shrink fits than that illustrated in the building of the large guns for the army and navy. These guns are made of a number of pieces. The first part is a long tube the length of the gun. Over this tube are fitted and shrunk a number of bands or hoops called *jackets,* and over these is fitted another set of hoops. Great skill is required in turning the jackets and the tube so that when the jackets are shrunk on they will exert a certain amount of compressive force, which varies along the length of the tube. A corresponding difference or allowance in the fit must be made to give the various pressures desired. The average allowance is from .0012 to .0015 inch per foot. Great skill is required to bore and turn these pieces to the correct size, as a difference of from .001 to .002 inch may be sufficient to cause rejection. When the jackets or hoops are put on a gun tube, they are first heated by wood or gas fires. When sufficiently hot, they are dropped over the tube standing on end in a pit. As soon as the jacket is in place, streams of water are turned on the tube to keep it cool and to cool the jacket.

FITTING ALLOWANCES

128. The fitting allowances given in Table IX represent good average practice for shafts from 1 to 8 inches in diameter. They also serve to suggest the allowances to be made on work of large diameter. The plus sign indicates that the diameter of the shaft is to be increased by the amount of the allowance,

and the minus sign indicates that the shaft is to be made smaller by the amount of the allowance. Judgment should always be used in determining the amount of allowance, as the values

TABLE IX

ALLOWANCES FOR DIFFERENT FITS

Diameter of Shaft Inches	+ Allowance on Shaft Inch			− Allowance on Shaft Inch	
	Press Fit	Drive Fit	Shrink Fit	Sliding Fit	Running Fit
1	.001	.00075		.001	.002 to .004
2	.002	.00075		.002	.004 to .006
3	.002	.00125	.00225	.003	.006 to .010
4	.002	.00125	.00300	.004	.007 to .011
5	.003		.00375	.005	.008 to .012
6	.003		.00450	.006	.009 to .015
7	.003		.00525	.007	.011 to .017
8	.004		.00600	.008	.012 to .018

suggested in the table may have to be increased or decreased to suit the strength of the work and the use to which it is to be put.

TERMS USED IN LATHE FITTING

DEFINITION OF TERMS

129. Description.—Turned and bored parts that are to be fitted together must have certain differences between their dimensions, so that the degree of tightness or looseness of the fits will suit the service required of them. Also, certain variations in the dimensions may be allowed in order to reduce the cost of production. For example, the bearings for heavy revolving parts, like rolling-mill machinery, are quite loose as compared with those required for small spindles and light loads. On the other hand, locomotive wheel tires must bind the wheel centers with the greatest degree of tightness.

Aside from the allowance for fitting previously mentioned, there are several other terms used in lathe work to denote the dimensions of the turned and bored parts that are to be fitted together. The most important of these are as follows: *Interchangeable, limits, tolerance,* and *clearance.*

130. Interchangeable Manufacturing.—In order to reduce the cost and to get the greatest production, a system known as interchangeable manufacturing has been developed. By this system the individual pieces of a mechanism are turned, bored, or otherwise machined in large numbers. The pieces are tested by gauges and other measuring instruments to predetermined dimensions, so that the pieces may be assembled without any further fitting. The repair of interchangeable work can be made simply by buying a new part and placing it in position. Also, parts may be taken from one machine and used on another of the same design. Familiar examples of interchangeable manufacturing are the sewing machine, the typewriter, and the automobile.

131. Limits.—In order to produce a machine at the lowest cost, the dimensions of its parts must not be made with unnecessary accuracy. Therefore, it has become common practice to state the dimensions of a piece in its two limits, which are the greatest and the smallest dimensions acceptable. Thus, if the diameter of a shaft is marked on a drawing as $2''\begin{smallmatrix}+.025\\-.005\end{smallmatrix}$, the limits of the turning and finishing operation are 2.025 inch and 1.995 inch. Likewise the diameter of a hole may be marked $2''\begin{smallmatrix}-.026\\+.001\end{smallmatrix}$, meaning that the limits of the diameter are 2.001 inch and 1.974 inch.

132. Tolerance.—The tolerance is the difference between the limits allowed on any single piece. Thus, if a shaft has limits of 2.025 inch and 1.995 inch, the tolerance is $2.025-1.995 = .03$ inch. The rate of production can be increased and the cost reduced by adopting the largest tolerance that can be used. The smaller the tolerance the greater the expense of produc-

tion, which includes the machining, testing, and assembling. On the other hand, machines made with small tolerances are close-fitted and finer, and the bearings are more nearly alike all over, so that one grade of oil is effective in all of them.

133. Clearance.—Clearance is the difference between the dimensions of the two parts when actually made and ready to be assembled. Thus, the diameter of a journal may measure 1.01 inch, and that of the bearing 1.03 inch. Then the clearance is $1.03-1.01=.02$ inch, which may be the room needed for the lubricant.

The clearance is the net result of the machining operations on the two parts, and it may not be identical in different pairs of assembled parts produced by interchangeable manufacturing. For example, if the limits of a journal are .993 inch and .995 inch, and of the bearing .999 inch and 1.002 inch, then the tolerance for the journal is $.995-.993=.002$ inch, and for the bearing it is $1.002-.999=.003$ inch. Therefore, if the piece having the smallest journal be used with the largest bearing, the largest clearance will be $1.002-.993=.009$ inch.

134. If the largest journal must be fitted in the smallest bearing, then the least clearance will be $.999-.995=.004$ inch. Between these two limits of clearance, .009 inch and .004 inch, may be other clearances depending upon the actual dimensions of the journals and bearings that happen to be paired from the supply of parts to be assembled. Therefore, some pins will be a loose fit in some holes and a tight fit in others. If selective assembling can be done, and the larger pins matched up with the larger holes, and the smaller pins with the smaller holes, a more uniform product will be turned out.

INITIAL CLEARANCE AND MAXIMUM METAL DIMENSION

135. Initial Clearance.—Frequently, especially on machine drawings, when considering the clearance from measurements of the pieces, there is a minimum or least clearance, called initial clearance, indicated by the dimensions on the drawing. It is the difference between the largest dimension of a pin or

journal and the smallest dimension of the hole or bearing. It is used to distinguish the smallest clearance given on the drawing from the actual, maximum or total clearance that may be produced.

136. Maximum Metal Dimension.—The term maximum metal dimension is sometimes used to express the dimensions of the parts when they contain the most metal. This means the condition when the hole is smallest and the pin or journal is largest, both parts thereby containing their greatest amount of metal.

LATHE PRACTICE

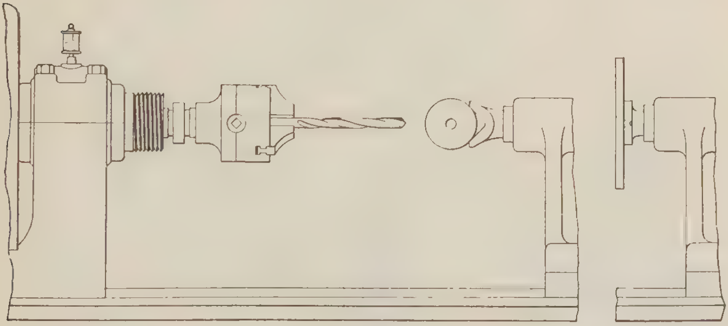
(PART 2)

COMMON AND SPECIAL LATHE WORK

COMMON LATHE WORK

DRILLING OPERATIONS

1. Methods of Holding Drill in Lathe.—The engine lathe may be used for drilling. The drill may be held by means of a chuck with taper shank that fits the spindle bore, and the



(a) (b)

FIG. 1

work held by hand against the dead center, as shown in Fig. 1. If round work is to be drilled on the diameter, as shown in (*a*), the work is held against the **V** center in the tailstock,

but if a plate or flat work is to be drilled, the pad center shown in (*b*) may be used. The work is fed toward the drill by the hand wheel of the tailstock.

The drill chuck may also be held in the tailstock spindle and the work set in the lathe chuck, and the drill fed into the

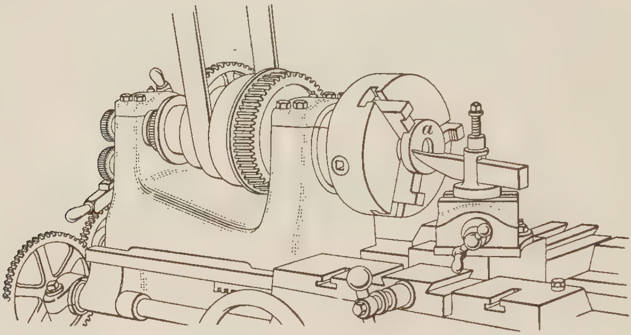


FIG. 2

work. In Fig. 2 is shown how a disk *a* may be faced, drilled, and reamed in one chucking. The lathe back gears are used to get the lower speed needed for drilling and reaming operations.

2. Starting a Twist Drill.—The twist drill should be started to run true and with its point centered before the outer corner of the drill has begun to cut. After the outside corner of the drill has entered the work, its position cannot be changed. It is best to make the starting point true by a centering tool in the tool post, as shown in Fig. 3. This tool is forged with a thin, flat point and is ground like the point of a flat drill. The hole is started true with the tool, after which

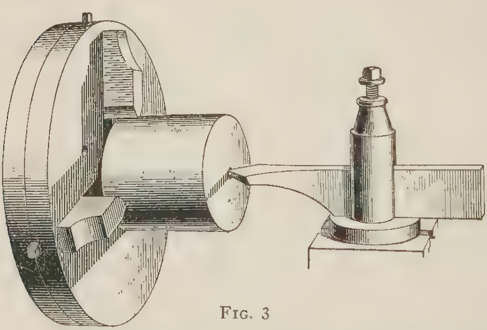


FIG. 3

the twist drill in the tailstock will follow in the hole previously started. A tool like that shown in the illustration, but made to cut on the front side only, is often used to turn the starting hole true. When this starting tool is not at hand, the twist drill may be started true by placing the butt of an ordinary lathe tool in the tool post, and so adjusting it that it just touches the land of the twist drill. This will steady the point of the drill efficiently, so that in most cases it will start true.

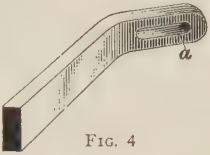


FIG. 4

The flat drill will either pierce a hole in the solid metal, or it will follow cored holes; but it will not cut so freely as the twist drill. In using the flat drill, a holder is employed as shown in Fig. 4. The holder consists of a flat piece of steel with one end bent at an angle. The slot *a* cut through the end is sufficiently large to allow the drill to pass through.

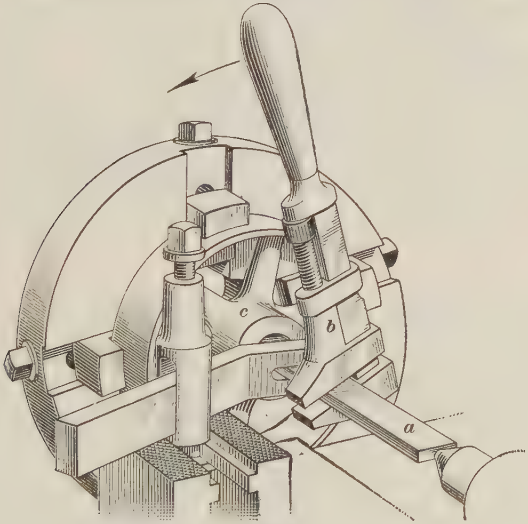


FIG. 5

In starting a flat drill, *a*, Fig. 5, it is brought forward by turning the hand wheel on the tailstock and held with the wrench *b* against the front side of the cored hole in the work *c* until a conical surface is produced that runs perfectly true.

If the drill does not run true before it has cut to its full diameter, it cannot be expected to run true at all.

3. Three-Lip Chucking Drill.—In Fig. 6 is shown a three-lip drill held on the tailstock center with a special holder *a* and supported in a steady rest *b*, and operating in the work *c* held in the jaws of the lathe chuck. This drill is used for roughing out cored holes or holes made by a smaller twist drill.

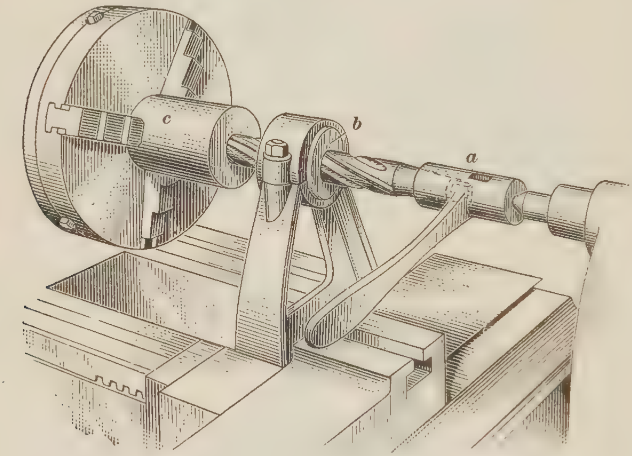


Fig. 6

4. Heavy Drilling Operations.—In drilling large and long holes, one end of the work is supported and driven by a chuck, and the other is upheld by one or more heavy steady rests, as in Fig. 7, which shows a shaft *a*, 60 inches long, in which a hole is being drilled 8 inches in diameter. The tool is forced into the solid forging without a pilot hole, and the cutting speed is very slow. An inserted-cutter two-lip drill *b*, shown in Fig. 8, is set in a long shank and clamped in the tool support *c*, Fig. 7, by the bolts *d*. The support *c* is firmly bolted to the lathe carriage, and the drill is fed into the work by the hand wheel *e*, or by means of the automatic feed of the carriage.

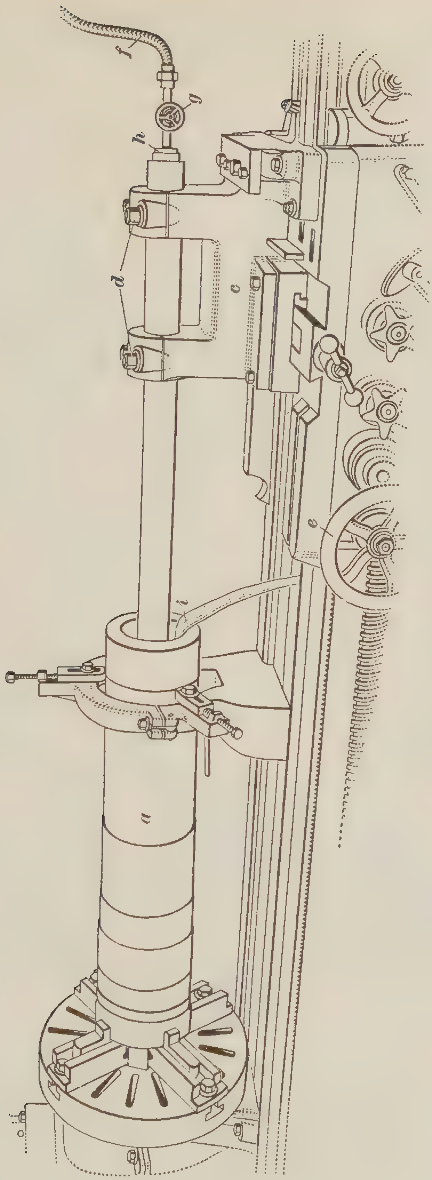


FIG. 7

The drill point is cooled by a flood of cooling liquid, introduced into the hollow shank of the tool through the tube *f*, the amount being controlled by the valve *g*. A gland *h* at the end of the shank prevents leakage of liquid. After cooling the tool, the liquid flows out of the bore at *i* into a receptacle in the base of the lathe from where it is pumped to the supply tank.

LATHE BORING OPERATIONS

5. Height of Lathe Boring Tool. The point of a boring tool is usually located slightly above the lathe centers, as shown in Fig. 9 (*a*). The purpose of this is to prevent the point from digging into the work and chattering when the tool springs downwards. If the point is set below the centers, as in view (*b*), it will dig into the work if deflected any lower. In views (*a*) and (*b*) the boring-bar center coincides with the work center. Where the work diameter is very large as compared with the bar diameter, as in view (*c*), the tendency to dig in becomes lessened, and in boring tapered holes in revolving

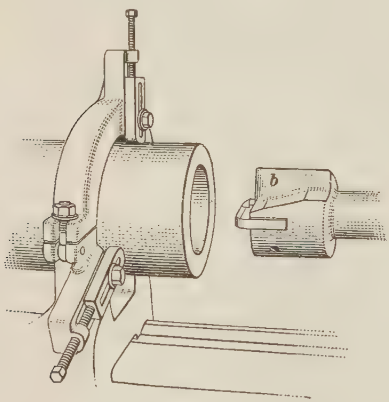


Fig. 8

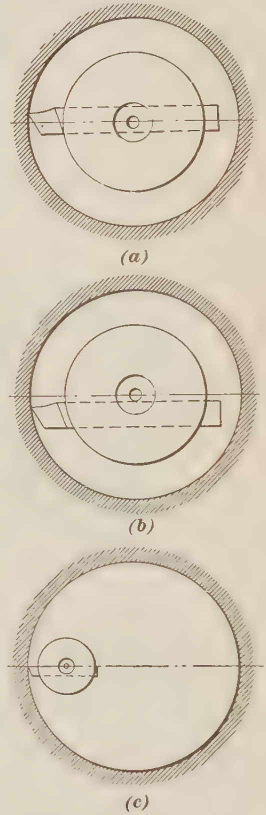


Fig. 9

work the point of the tool must be set level with the centers. If set above or below the centers the taper will be changed, as explained later.

When small holes are to be bored, the bar *a*, Fig. 10, may nearly fill the hole, which allows a very short projection *b* of the tool outside the bar. The cutting point *c* may be quite high, but its cutting action will be good. The center of the work is at *d*, and of the bar at *e*.

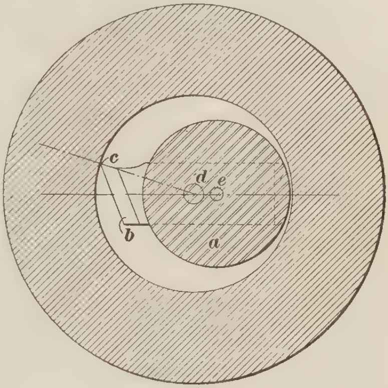


Fig. 10

6. Boring Pulleys With Lathe.—Suppose a cored pulley hub is to be bored with the tool set as shown in Fig. 11. The tool is clamped rigidly in the tool post so that it lies parallel with the lathe **V**'s and so that it will pass through the hole in the work. It should be set with the cutting edge level with the center of the work. Both roughing and finishing boring cuts are started at the front end. Roughing cuts should be as heavy as possible,

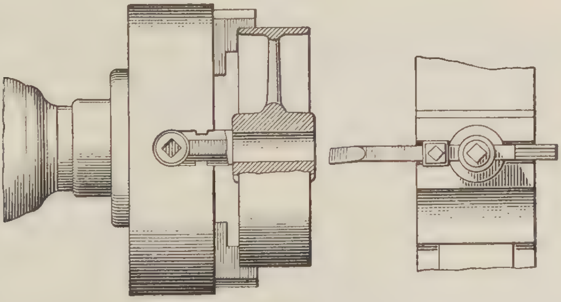


Fig. 11

but they should never be heavy enough to cause any spring of the tool. After the first cut the hole should be calipered to see whether it is being bored parallel. If it is found to be tapered, lighter cuts should be taken. Sometimes the hole

may be made parallel by reversing the direction of the feed, which will start the cuts at the back end of the hole. If the hole is to be finished by boring, the last cut should leave a smooth surface; but if a reamer of the required size is available the hole can be bored $\frac{1}{32}$ inch too small and finished by running the reamer through at slow speed, while the pulley is still in the chuck.

7. Boring With Bar Between Lathe Centers.—Boring may be done by a bar held between the lathe centers. The work is clamped to the carriage and the cutters are held in slots in the boring bar, or in facing heads clamped to the bar. When each of the tools in the boring bar is doing its share of the work, the bar is well balanced in the cut, and the strain on the lathe centers is small. If the cut is very heavy on one side and light on the other, the opposite cuts will be unbalanced, the heavier cut tending to spring the bar away and into the

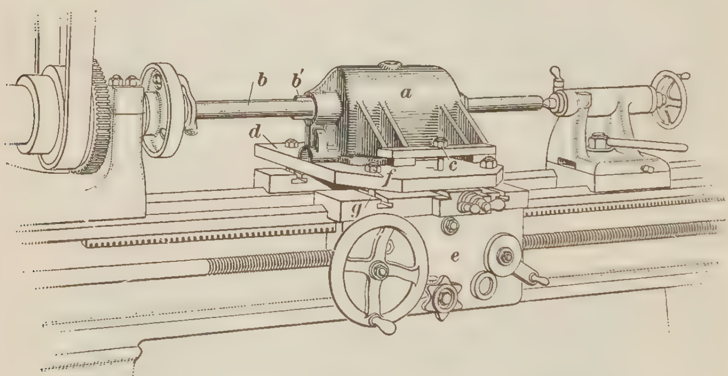


FIG. 12

lighter cut on the opposite side. This action will bring a great strain upon the centers of the lathe. If a surface to be bored is much out of true, it is best to true it by taking a number of light roughing cuts to prepare the work for the finishing cut.

8. In Fig. 12 is shown a gas engine crank-case *a* being bored by a boring bar *b*, with two cutters *b'* and held on the centers of the lathe. The work is clamped in position by the

stud *c* to the plate *d* that is bolted to the saddle *e*, the regular tool rest of the carriage having been removed. The plate *d* may be slightly raised or lowered, so as to adjust the work to the boring bar, by turning the nuts *f* on the bolts that hold the plate to the saddle, and then locking the plate by the nuts *g* on the underside of the plate.

9. Boring an Engine Cylinder.—The general scheme of using the traverse-head bar for boring an engine cylinder is

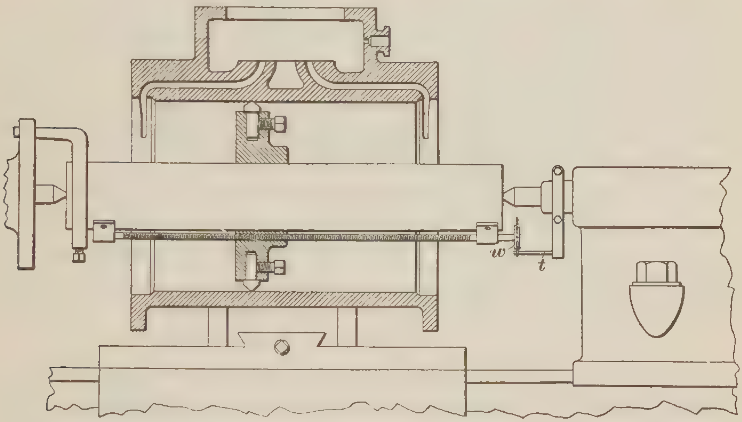


FIG. 13

shown in Fig. 13. The cross-slide is removed from the lathe and the work is set on blocking and clamped with bolts in its correct position. Considerable care should be taken in setting this class of work on the machine, to see that it is so set that all faces can be finished in their correct relation to one another and to correct sizes. The bar passes through the work, is held between the lathe centers, and is driven with a dog, or by clamps and studs from the face plate.

After the work has been carefully set up on the saddle of the lathe so that it will not be sprung out of shape when the clamps are put on to hold it down, it must be centered by calipering with the inside calipers between the bar and the top, the bottom and two sides of the hole at each end of the bore. The cut is then started at one end with a single tool

until the proper diameter is found. Then the other tools are set so as to share the cut equally.

10. One of the various methods of operating the feed-mechanism is by means of the star feed, as shown in Fig. 13. A star wheel *w* is fastened to the end of the feed-screw, which revolves with the bar. A pin *t* is fastened in some convenient place so that for each revolution of the work it strikes one of the arms in the star wheel and gives it a partial revolution. When a coarser feed is desired, two or more pins may be arranged to act one after the other. By this means the feed-screw is revolved, and so gives motion to the head. Another method of revolving the feed-screw is to put a gear in the place of the star wheel. A second gear is fixed to the lathe center so that it gears with the wheel on the feed-screw. As the bar revolves, the gear and the feed-screw rotate about the fixed gear, thus revolving the feed-screw on its axis. If the gears are of the same size, the screw will make one revolution for each revolution of the bar. By varying the sizes of these gears, various rates of feed may be obtained.

11. The traveling-head bar is more desirable for large work than the bar with the fixed head because the sliding head-bar need be but little longer than the hole through the work to be bored, and it is consequently stiffer. When the bar has a sliding head, the work does not need to be fastened to the carriage of the lathe, but may be bolted more securely to the lathe bed. This also adds to the rigidity of the work.

12. Boring Tapers With Taper Attachment and Compound Rest.—Taper boring is often done on the lathe. The work may be held in a chuck, or on a face plate, or with live center and back rest, and the taper may be bored by using the taper attachment set opposite to that required for turning the same taper. The attachment is set in the same way as for taper turning, and the operation of taking the cut is the same as in boring cylindrical holes. When the holes to be bored are short or an abrupt taper is desired, the compound rest may

be used. For some kinds of work, taper reamers are employed. They are held in the tailstock the same as the ordinary chucking tools.

13. Reaming Tapers.—Tapers may be reamed by a tool or tools inserted in the cutter head of a boring bar. The tools must be in the form of blades as long as the hole, and set so that their cutting edges form the required angle.

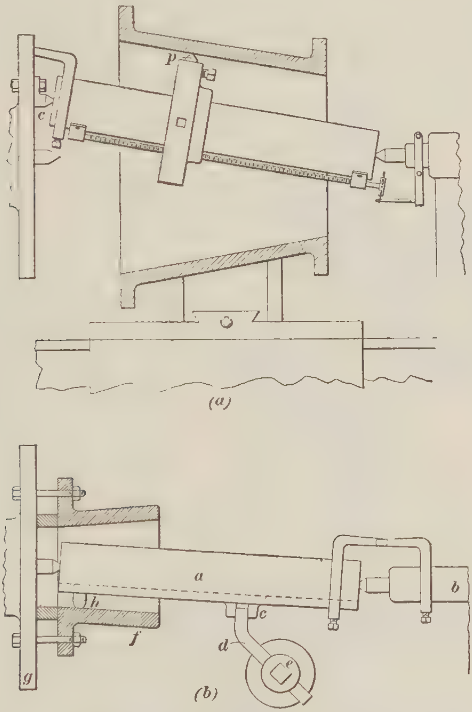


Fig. 14

14. Boring Tapers With Traveling-Head Bar.—When the boring bar with the traveling head is used, a tapered hole may be bored in work fastened to the carriage or bed by setting over the headstock end of the bar. The bar is set over by clamping a false center *c*, Fig. 14 (*a*), to the face plate, and adjusting it at any required distance from the true center of

the lathe. The amount that this center is to be set out of line may be estimated in the same way as the amount that the dead center is set out of line in plain taper turning. When the bar is thus set out of line, only one cutter point *p* can be used.

The setting to this position is made by turning the live spindle so that the false center is brought toward the front of the lathe and until it stands with its point at the same height as the points of the live and dead centers. In this position all three centers measure the same height above the **V**'s of the lathe. The cutting edge of the tool is set to the same height. This makes all of the measurements from one fixed point.

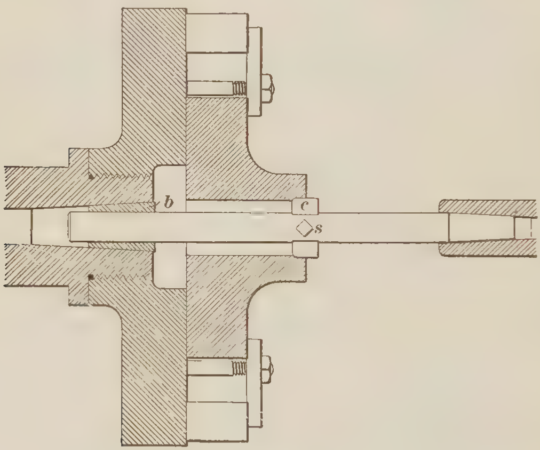


FIG. 15

15. Boring Tapers With Slotted Bar.—The slotted boring bar shown in Fig. 14 (*b*) may be used for either straight or tapered holes. The tool bar *a* is held on centers, and clamped to the dead-spindle end *b* so that it cannot rotate. Throughout its length it has a **T** slot or a dovetail slot that carries a sliding cutter. The cutter has lugs *c* that engage the end of a feeding piece *d* held in the tool post *e*. The work *f* may be clamped to the face plate *g* as shown. As the feeding piece *d* is fed along the lathe, it will force the sliding cutter fitting the slot to feed along the bar *a*, so that the cutting point *h* will bore either a tapered or a cylindrical hole, depending on the position

of the dead center. The live center rotates in the stationary bar, and hence it should be hardened and supplied with oil. It is also necessary to feed the tool post in by means of the cross-slide as the cut advances, so as to prevent the lugs *c* from passing out of contact with the feeding piece *d*.

When the holes to be bored are long, a bar can sometimes be used, as shown in Fig. 15. The cutter *c* is held in the slot cut in the bar by a setscrew *s*. One end of the bar is held in the tailstock spindle, and the other end fits a tapered bushing *b* in the live spindle. Support is thus provided for each end of the bar, which is necessary in order to produce a true hole. These cutters are often made in sets of two or three, to be used in regular order to rough and finish the hole.

16. Use of Calipers and Gauges for Measuring Bored Holes.—Greater skill is required for measuring the diameters of holes than for measuring outside work. The holes may be measured by the use of plug gauges, limit gauges, or inside calipers. When inside calipers are used, they may be set from a standard ring gauge, from a scale, or from a pair of outside calipers that have previously been set from a scale. In setting an inside caliper from a scale, one end of the scale should be held squarely against a block, as shown in Fig. 16, and the caliper adjusted to the line on the scale.

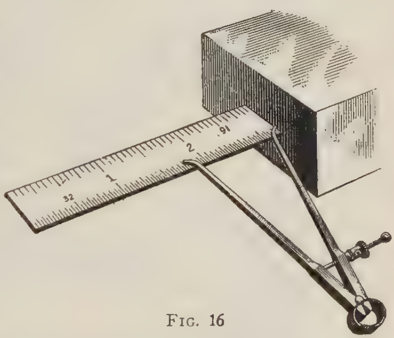


Fig. 16

17. When work is measured with inside calipers that have been set from outside calipers, there is chance for error in adjusting the outside calipers, in transferring the size to the inside calipers, and in the final measuring. It will be seen by reference to Fig. 17 that in order to measure accurately the calipers must be held in line with the axis AB of the hole. If the calipers were held in any other line, as, for example, CD, the hole would appear too large; for, with one point resting

against the work at b the other point a would be in the position a'. When the solid plug gauge is used for testing, extreme care is necessary. If the hole is the exact size, the gauge will enter only when its axis is held exactly in the line AB; because of this, the work is often bored too large, as insufficient care is used in making the trial.

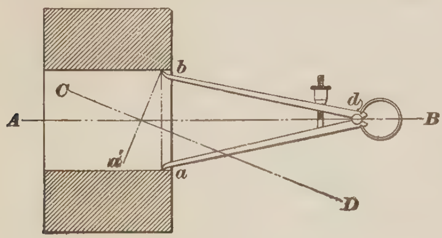


FIG. 17

If, in calipering a hole, it appears to be very close to size, a second cut may be run through without adjusting the tool deeper. A sufficient amount may often be removed by this second cut, its depth depending on the

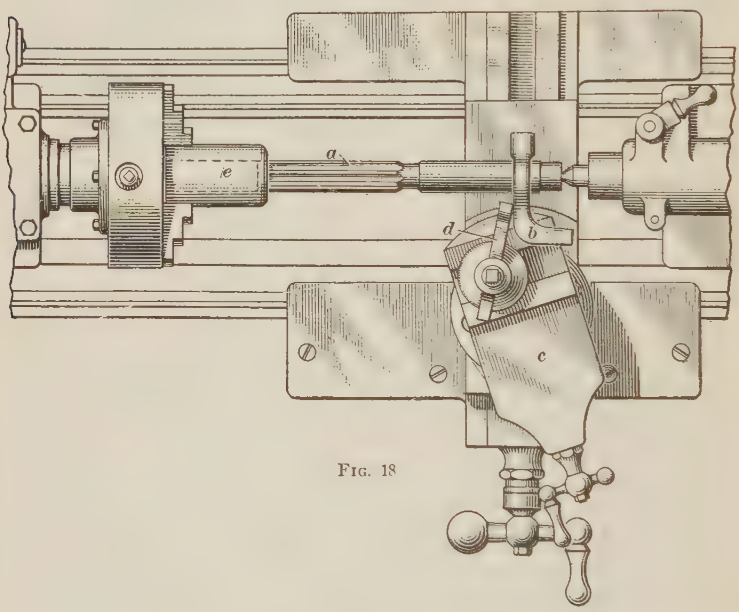


FIG. 18

spring of the tool during the previous cut. When the hole is large enough to admit heavy tools, they should be used to avoid the spring as much as possible.

REAMING OPERATIONS

18. After work has been drilled in the lathe, the holes are frequently reamed to exact size. Care must be taken to use a low speed and take light cuts in reaming because otherwise the reamer may bind in the hole and cause damage. A method of holding a reamer in the lathe so that it will not

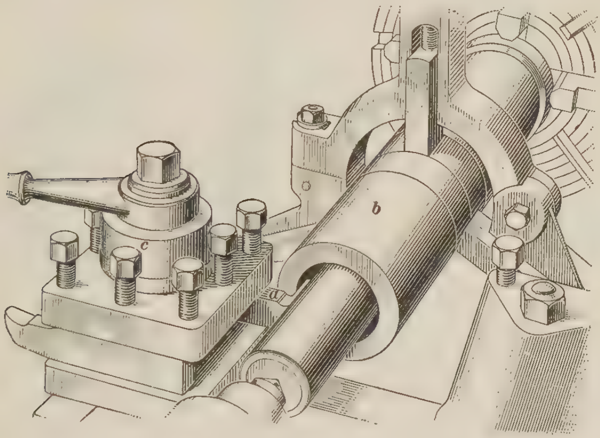


Fig. 19

bind, is shown in Fig. 18. One end of the reamer *a* is placed on the dead center, and a lathe dog *b* is attached to the reamer, as shown. The compound rest *c* is then adjusted so that the dog rests on top of the rest, against a lathe tool *d* clamped in the tool post. In this way the reamer is prevented from turning and is held back on the dead center by the tool in the tool post. The reamer is then fed into the work *e* by the aid of the tailstock hand wheel and drives the carriage before it, the weight of the carriage preventing the reamer from gripping or binding.

LATHE TREPANNING

19. The operation of cutting grooves or recesses concentric with the circumference of the work is called *trepanning*. Cutting rings and washers are common examples. As there

is no standard trepanning tool, each must be forged to suit the work. In Fig. 19 is shown a trepanning tool *a*, of the shape illustrated in Fig. 20, cutting a groove in the cylinder *b* held on

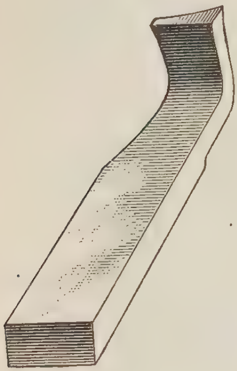


Fig. 20

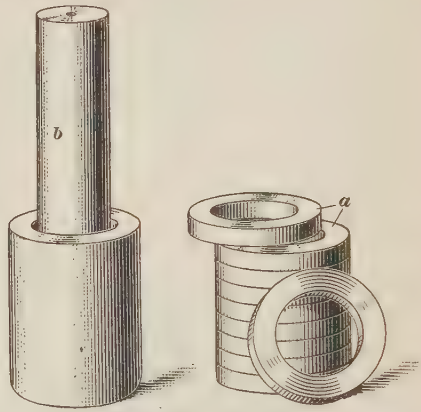


Fig. 21

the lathe centers. When the tool has cut to a certain depth the turret tool post *c* is indexed and the cutting-off tool brought in position to cut off the rings *a* as shown in Fig. 21. At *b* is shown the core of the cylinder which remains intact. In Fig. 22 is shown a trepanning tool cutting a recess in the end of a piece

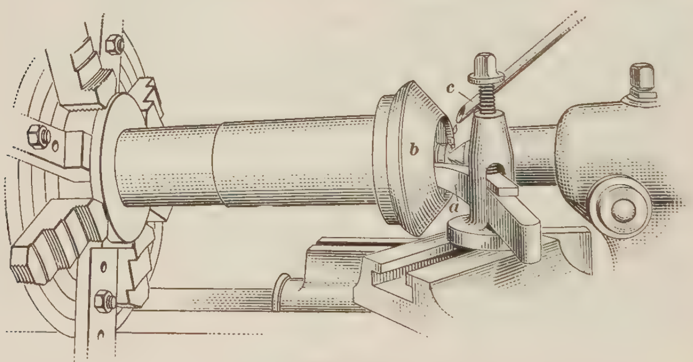


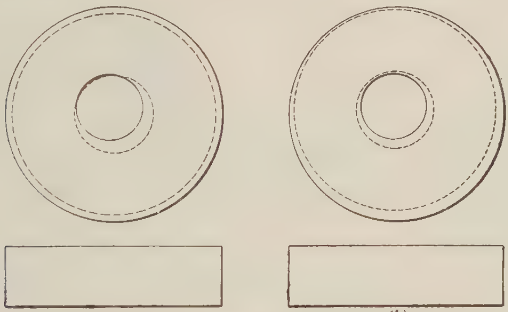
Fig. 22

of chucked conical work held on the tail center. The pipe *c* directs a stream of oil on to the cutting point. Tools of the inserted-blade type are often used for trepanning operations.

CHUCKING OPERATIONS

20. Starting Lathe Chucking Tools True.—If a cored hole does not run true, the chucking tool will not start true, the tendency being to follow the cored hole. In order to start the tool true, a common boring tool may be used and the mouth of the hole bored out to nearly the correct size, so that the tool will enter $\frac{1}{8}$ inch or so. A bearing all around is so given, and the tool held true.

21. Example of Chucking.—Suppose that a disk, as shown in Fig. 23 (*a*), with a hole cored very much to one side,



(*a*) (*b*)

Fig. 23

is to be bored, and turned to a given size. If set in the chuck so that the outside runs perfectly true, the cored hole would be so out of true that it could not be finished. If the cored hole is set to run true, then the outside could not be finished to size. In such a case, the work should be so set that both the outside and the cored hole run only enough out of true to equalize the difference. By thus dividing up the eccentricity, or the amount by which the outside and the hole are out of center, it will be found that the work can be finished all over to the desired size, as shown by the dotted lines in (*b*) lying wholly within the outline of the work.

22. Spring of Work From Pressure of Jaws.—When the work is light or frail, there is much danger of springing

under the pressure of the jaws necessary to hold the piece. In gripping a piece, advantage should be taken of the shape of the work to have the jaws of the chuck come against the more solid parts. For example, in chucking a pulley, it should be so set that the jaws come opposite the arms of the pulley. The pulley is later put on a mandrel and turned, which will correct the springing. Suppose that a ring is held in the chuck, as shown in Fig. 24. When the jaws are tightened, the work is sprung opposite each jaw. If a cut is taken the work will be bored true and round while under pressure of the jaws. When this pressure is relieved, it will be found that the work will no longer be true, but will spring back to its normal shape. This will cause the work to be out of round, as shown in Fig. 25, the dotted lines indicating the true circle. In such cases the jaws of the chuck should be loosened and the ring reset before the finishing cut is taken. The jaws should be tightened so that the pressure will be just sufficient to hold the work during the light finishing cut.

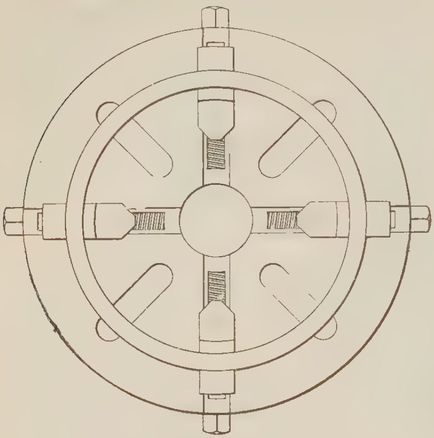


Fig. 24

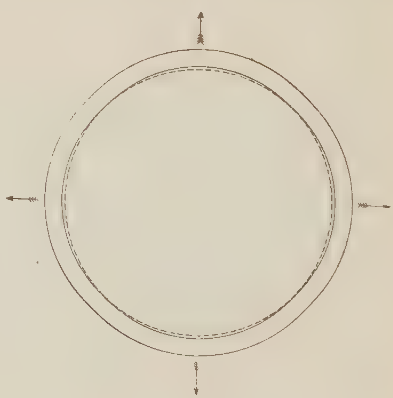


Fig. 25

23. Setting Work in an Independent Chuck.—To set a round piece in an independent chuck, if the work is at all heavy, it can be held against the chuck by using a block

of wood between the work and the dead center, as shown in Fig. 26. This will prevent the work from falling out while the jaws are being adjusted. The jaws are tightened only enough to hold the work. The lathe is started at a moderately fast speed, and the work is tested by holding chalk near its face. If the work does not run true, the chalk will touch only the high side. This indicates that the work should be moved. If the chalk touches the work as shown by the line *a b* it would indicate that the jaw opposite jaw *1* should be loosened, and jaw *1* tightened, thus moving the work across the face of the chuck. If the chalk touches between the two jaws, then the

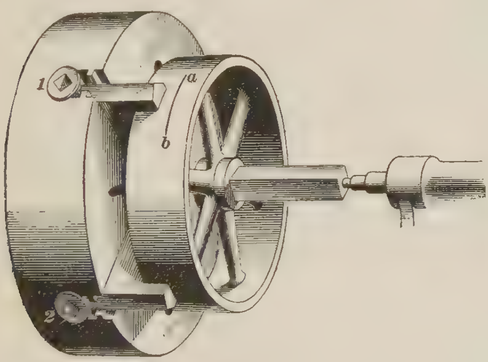


FIG. 26

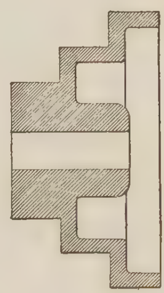


FIG. 27

two opposite jaws must be loosened, and the two front ones tightened a corresponding amount. The amount that each jaw is moved should be observed, as it will help to determine the amount of subsequent movements. This is continued until the chalk touches at points evenly all around. Another way of setting work in a chuck is to tighten the jaws around the work and run a lathe tool up to the work until it almost touches the work. The spindle is then revolved by hand and the tool point is watched to see whether the work runs true or not.

24. When the work is to be turned or faced on a number of faces, each face should be tested in setting the work before beginning to turn any one face. For example, take the cone pulley, Fig. 27. Here the hole must be bored true, and the

inside and outside of the cone bored and turned. If the casting is perfectly true, the work may be set by any one face, and the others will naturally run true, but this is not often the case. All parts should be tested to see whether there is enough stock and whether all surfaces run true enough to turn to size.

25. Clamping Regular Work.—In Fig. 28 is illustrated a simple method of clamping a large flange to a face plate, when it is only desired to bore the hole in the center of the flange, and to face the hub *f*, the surface *r* being left rough. This method will do very well where the back face of the flange may

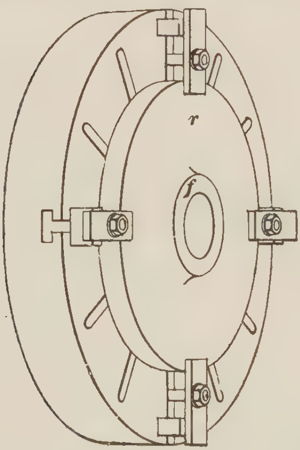


Fig. 28

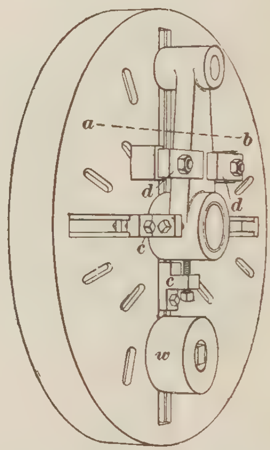


Fig. 29

be clamped directly to the face plate or on parallel blocks, and where but a single hub is to be operated on. If it becomes necessary either to face the surface *r* or to operate on a number of pieces, it is best to use jaws similar to those illustrated at *c* in Fig. 29. The work may then be placed against the shoulders below the setscrew points.

26. Clamping of Rocker-Arm.—When it is desired to clamp a rocker-arm similar to the one shown in Fig. 29 three chucking-block jaws *c* may be used. They are placed to bear against three points of the large hub of the rocker-arm as shown. The work is held securely against the face

plate by means of the two clamps *d*. Fig. 30 is a section on the line *a b*, Fig. 29, and shows the arrangement of the clamps and blockings; *e* is the arm, *d* the clamps, *g* the blocks, and *f* the bolts. Care should be taken to see that the blocks *g* are of exactly the height of the work, so that the clamps *d* will set level or parallel to the face plate. *The bolts f should be as close to the work as possible.*

27. If strain is brought on the work *e* by the clamps *d*, Fig. 30, it is evident that there will be danger of springing the arm between its hubs or bosses. To overcome this, a block is placed under the arm, on each side, as shown at *j*. In order to balance the portion of the rocker-arm extending to one side of the center and the clamps and bolts *d* and *f*, a counter weight *w*, Fig. 29, may be attached to the opposite side of the face plate, as shown, and adjusted in or out until it balances the whole exactly. Such work as this, which has a number of faces that must be finished in certain relations to one another, should be laid out before attempting to set it in the chuck or on the face plate. The work is to be bored to the circle indicated by the dotted line, and may be set so that it will run true with this circle by testing with a scriber or pointed tool held in the tool post.

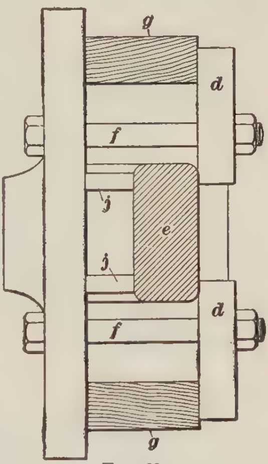


Fig. 30

28. Use of Paper on Face Plate.—When a finished surface is to be clamped against the face plate or any other metal surface, the danger of its slipping can be greatly reduced by putting a slip of paper between the two surfaces where each clamp is applied. If this precaution is not taken, it will be found almost impossible to clamp the work so that it will resist the action of the boring and turning tools.

29. Pulley Clamp.—Pulleys that must be bored and turned can be clamped by means of the arms. Fig. 31 illustrates a clamp intended for this purpose. The block *a* is bolted to the face plate and supports an adjustable clamp *c* having a turned portion that fits in a socket in the block *a*, and is secured by the setscrew *d*. The pulley arm *b* is held in the clamp *c* by the setscrew *e*. Similar clamps can be devised for holding a great variety of irregularly shaped work.

30. Use of Angle Plate on Lathe Face Plate.—A very convenient attachment for face-plate work is the angle plate, as shown at *a*, Fig. 32. This angle plate is so made that its two faces are at an angle of 90° with each other, and it is used

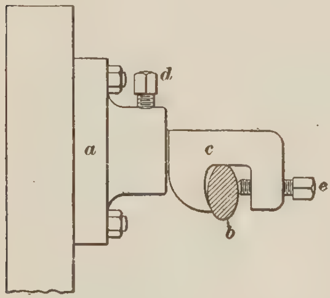


FIG. 31

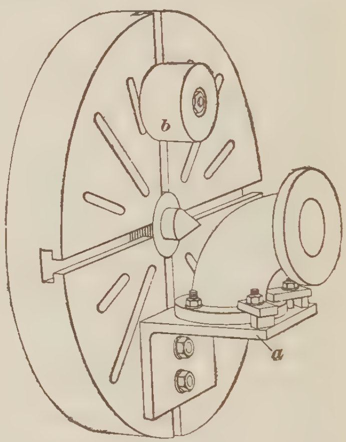


FIG. 32

when it is desired to finish two faces of a piece square with each other, as, for instance, the flanges of a pipe elbow. One face is clamped to the angle plate as shown. This holds the other face of the elbow in such a position that it will be cut square with the first face. This angle plate may be used to great advantage for many operations in face-plate work. As the angle plate and work are almost entirely on one side of the face plate, a weight *b* is usually attached to the opposite side for counterbalancing. If the surface to be machined is small in diameter so that the lathe can be run at high speed, care should always be taken to counterbalance any unbalanced parts.

31. Special Lathe Chucks.—Some work is of such shape that the ordinary lathe chuck will not hold it with sufficient rigidity to take heavy cuts. In this case, special chucks may be made when there are enough pieces to be turned to warrant the cost. For example, the cone pulley shown in Fig. 27 may best be held in a special chuck, such as that shown in Fig. 33. This chuck consists of a bell-shaped casting *a* that is fitted to the spindle *b* of the lathe. The outer end is bored to receive the work *c*, which is held in place by setscrews *d* at the sides. This form of chuck holds the work with great rigidity and makes possible the taking of heavy cuts that otherwise could not be made. It is also used to a large extent for special manufacturing purposes in many shops. For special work, other forms of chucks may be devised that depend on the shape of the work.

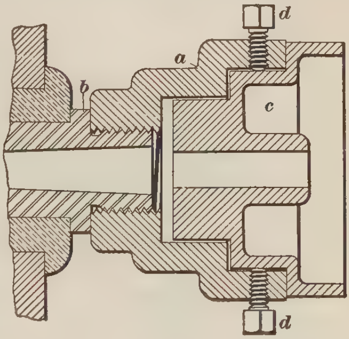


Fig. 33

MULTIPLE TOOLING

32. Attachments for Multiple Tooling.—The ordinary engine lathe is the machine best adapted to single-piece operations. In order to increase the range of the engine lathe for the production of quantity work and yet retain its simplicity, multiple-tooling attachments have been devised. In these attachments ordinary ground or forged lathe tools are used instead of the special tools that apply to the turret lathe and the automatic machine.

One form of multiple-tooling attachment is shown in Fig. 34. A plain rest *a* is mounted on top of the cross-slide *b* in the rear and the compound rest *c* in the front. In other forms several tools may be held in suitable tool holders, or tool blocks, mounted in front as well as in the rear of the carriage. In Fig. 35 is shown a turret tool post arranged to hold four tools and located on the compound

rest, and tool holders *b* are mounted in the rear on a cross-slide *a*.

33. The front tool block is generally used to hold tools for turning the work while the rear block may be used for grooving or forming tools. When roughing and finishing cuts are to be taken it is good practice to place the roughing tools in the front tool block and the finishing tools in the rear. The reason for this is that the cutting action on the front block is downwards against the cross-slide and therefore the front block may be used for heavy cutting. The rear block, however, is subjected to a lifting action and is therefore more suitable for lighter cuts.

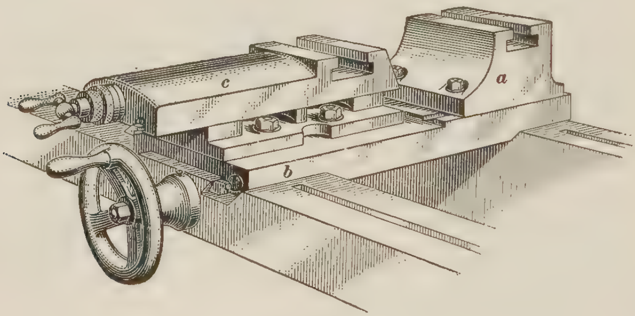


FIG. 34

34. Advantages of Multiple Tooling.—Multiple tooling not only affects a saving in time owing to the fact that tools in one tool rest may be set up while the tools in the other rest are operating on the work, but often it is possible to operate both front and rear tool rests at the same time. The tools in front of the work may be roughing while the rear tools are finishing the work close behind the roughing tool.

35. Gang Blocks in Multiple Tooling.—Several combinations of tool blocks may be made so as to allow for different spacings of cutting tools. In Fig. 35 the gang block illustrated consists of four separate tool holders that are adjustable along the dovetail groove. They are reversible, so

that they may be used either face to face, as at *c–d*, back to back as at *d–e*, or face to back as at *e–f*.

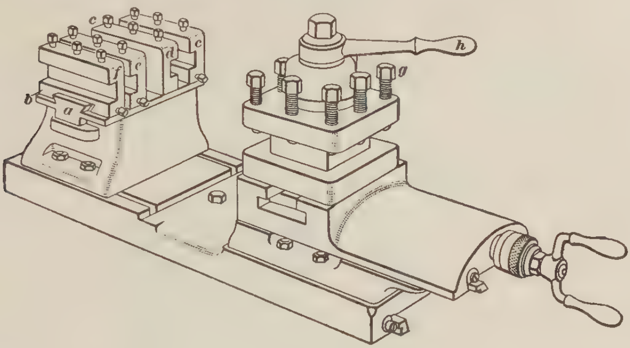


Fig 35

36. The turret on the front rest holds four tools that are clamped by the hardened setscrews *g*. Turning the binding lever *h* releases a pin from one of the notches in an indexing ring inside the turret. The turret may then be raised and revolved by hand until the next cutting tool comes into position, and is then locked again by the binding lever.

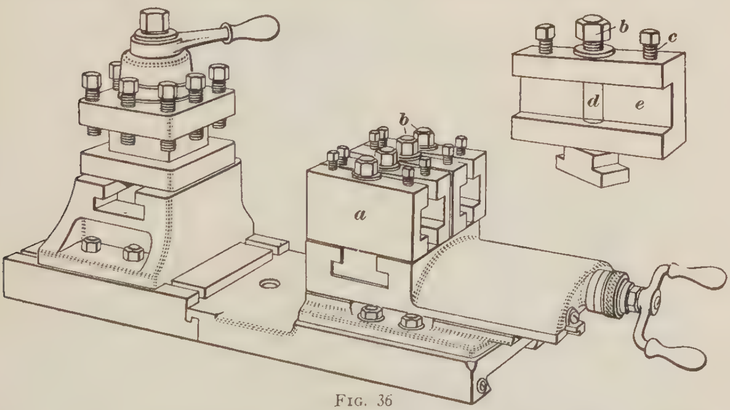


Fig. 36

In the arrangement, shown in Fig. 36, the tool blocks *a* are made to swivel. By unscrewing the nut *b* the upper part *c* of the tool holder can be made to swing around the pin *d* which has been cut away to fit the groove *e*. The blocks

are also reversible so that they are suitable for a number of combinations of cutting tools. The swiveling action of the tool blocks is sometimes desirable in order to present tools to the work at an angle.

37. Example of Multiple Tooling.—An illustration of how the principle of multiple tooling may be used to advantage, is shown in Fig. 37. The shaft *a* is being operated on by the four turning tools in the block *b* and by the four

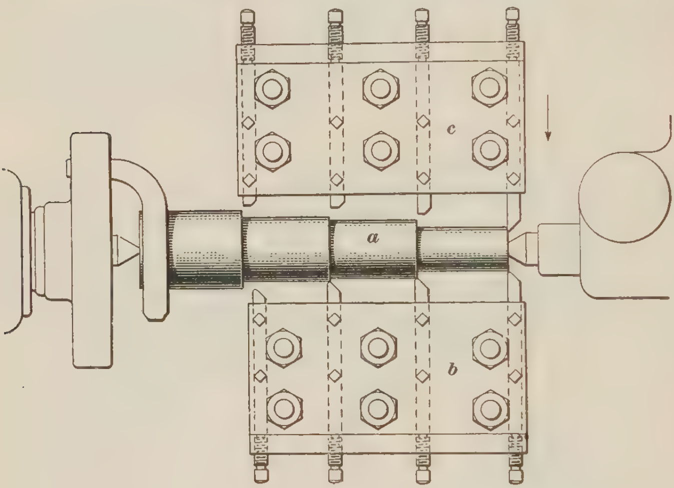


Fig. 37

facing tools in the rear block *c*. On some work both the tool slides may operate at the same time. Numerous tool combinations may be made up in this way.

38. Correct Setting of Tools in Four-Stud Holder. An attachment for the quick insertion of a cutting tool, at any desired angle, is shown in Fig. 38 (*a*). The tool *a* is held in position by the clamps *b* fastened by the studs *c*. It is important that the tool be clamped in the proper position, as shown in (*a*), where the pressure of the cut is in line with the feed-screw. If the tool *a* be incorrectly held, as in (*b*), the cutting pressure will be against the side of slide *d* and likely change the angle of the compound rest.

MULTIPLE STOPS FOR LENGTHS AND DIAMETERS OF WORK

39. Advantage of Using Multiple Stops.—The efficiency of multiple tooling may be greatly increased by using multiple stops for diameters and lengths of the work. They are

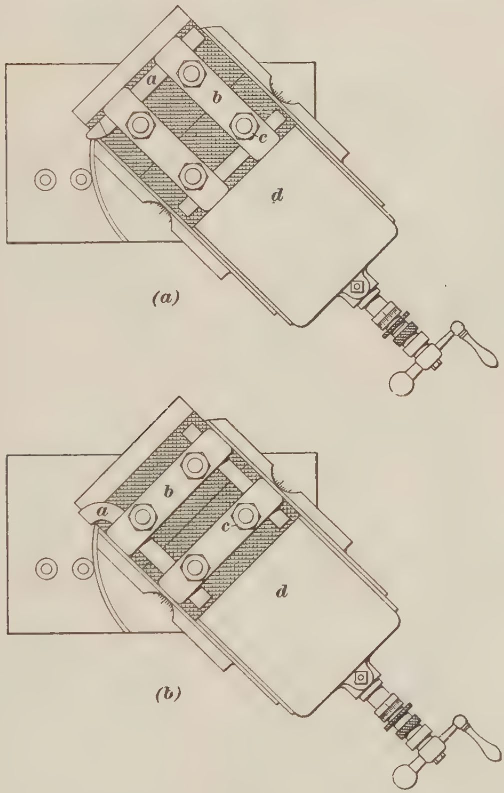


FIG. 38

especially useful for duplicating shafts or castings having several shoulders. A regular lathe tool carried in the front tool holder does the turning. After the length feed is automatically tripped when the first shoulder position has been reached, the cross-slide is fed toward the operator; this withdraws the front tool from the cut and brings up the rear tool

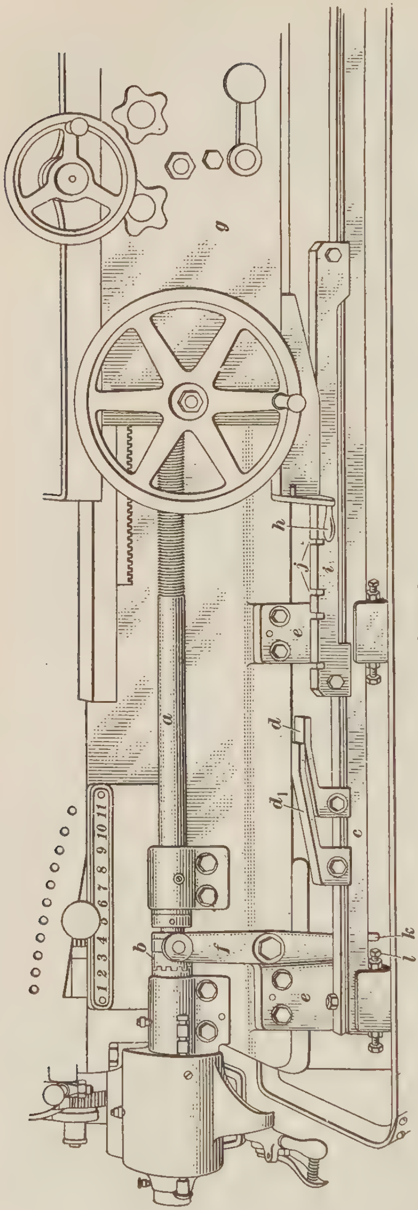


Fig. 39

to square the shoulder quickly. The diameter stop device is then turned to the next position, the tool is fed to the point determined by the diameter stop, and the length feed is reengaged.

40. Multiple Length Stops.—The multiple-length stops are illustrated in Fig. 39. The lead screw *a* is splined and used as a feed-rod. Near the end of the lead screw is mounted a clutch *b* that engages or disengages the lead screw from the feed-gear. The clutch is held in the engaged position by spring pressure. Beneath the apron is a bar *c* with a dovetailed surface along which a number of sliding dogs *d*, d_1, etc., can be clamped in any desired position. This bar is mounted in brackets *e* screwed to pads provided on the front of the bed, and is capable of a short end movement which is transmitted by a pivoted lever *f* so as to disengage

the clutch b on the lead screw a, and thus automatically stop the movement of the carriage.

41. Underneath the apron g, and attached to it, is a handle h capable of swinging in a vertical plane. The stop-dogs d and d_1 are so adjusted that when the lathe tool has cut to the first shoulder on the work, the handle strikes the first dog d, thereby throwing out the feed and stopping the carriage. To reengage the feed, in order to turn the work to the next shoulder, the handle h is raised so as to clear the stop-dog d. The spring in the clutch b will then throw the clutch into mesh again. When the next shoulder is reached, the handle h strikes the second dog d_1 that is slightly higher than the first dog, and the feed is again stopped. As many dogs may be placed on the bar c as there are shoulders on the work, and the dogs are made telescoping so that they can be set short distances apart.

For production work on many pieces of work of the same shape, a spacing bar i may be used together with one dog d, instead of several adjustable dogs. The spacing bar has several notches j that are the same distances apart as the lengths between shoulders on the work. The handle h successively drops into each one of these notches. The spacing bar travels, then, with the carriage until the end of the bar strikes the lower part of the dog d, and in this way stops the feed.

The handle h trips the feed just a little ahead of the correct shoulder position on the work. A slight hand movement of the carriage brings a projection k on the bar c up against an adjustable screw l on the bracket e and forces the carriage to a positive stop at the correct shoulder position.

42. Multiple Diameter Stops.—An attachment to limit the cross movement of the tool, is shown in Fig. 40. The several stops, as a, are mounted in the parallel slots in a cylinder b, and may be clamped at any point along the cylinder. There is a block c attached to the cross-slide d, and the movement of the cross-slide stops when the block c

strikes one of the projections a. The cylinder b may be revolved by the knob e so as to line up any stop with the block c. The cross-feed is operated by hand when these stops are used.

SPECIAL LATHE WORK

TURNING ODD-SHAPED WORK

43. General Remarks.—While much of the turning consists of plain cylindrical or tapered work mounted on the lathe centers or in chucks, as previously illustrated, there

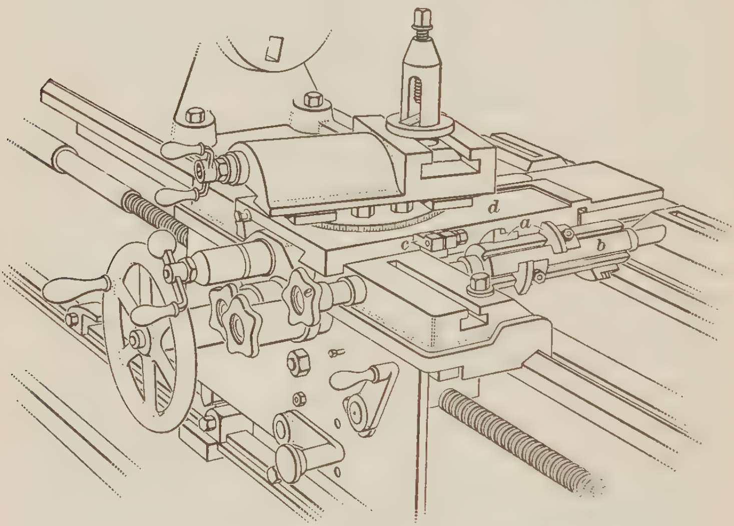


FIG. 40

is a great variety of specially shaped work that requires some additional arrangement of the lathe, the tool, or the holding devices. The examples of these special operations that follow are intended as useful suggestions to the operator when he must depend on his ingenuity to arrange the lathe to turn some unusual piece of work.

44. Turning With Rotating Tool.—Occasionally, a trunnion, or projection, on a large and heavy casting must be turned. If such a casting were rotated on centers, a very large lathe would be required.

In Fig. 41 is illustrated a method by which the turning has been done successfully. The casting *b* is long and heavy

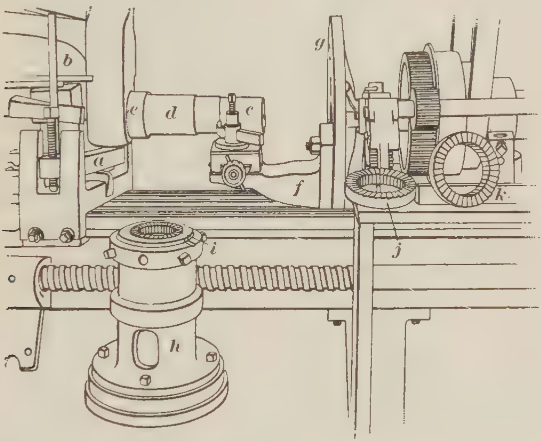


Fig. 41

and is supported at the inner end on a carriage *a*, and at the farther end on a special carriage not shown in the illustration. The portions *c*, *d*, and *e* must be turned to three different diameters. They are roughed by a tool attached to the special arm *f* that revolves with the face plate *g*. After the three diameters have been roughed out, the face plate *g* is unscrewed from the spindle and the attachment *h*, shown in the foreground, is substituted for it. This attachment carries a hollow mill *i*, that is used to finish the portion *c*, and after this portion is finished the mill shown at *j* is substituted to finish the portion *d*, and the mill shown at *k* to finish the portion *e*. The mill always revolves at the same distance from the face plate or end of the spindle, the work being fed into or past the revolving tool by means of an ordinary feed on the carriage *a*. It is also possible to finish entirely by the turning tool or by grinding.

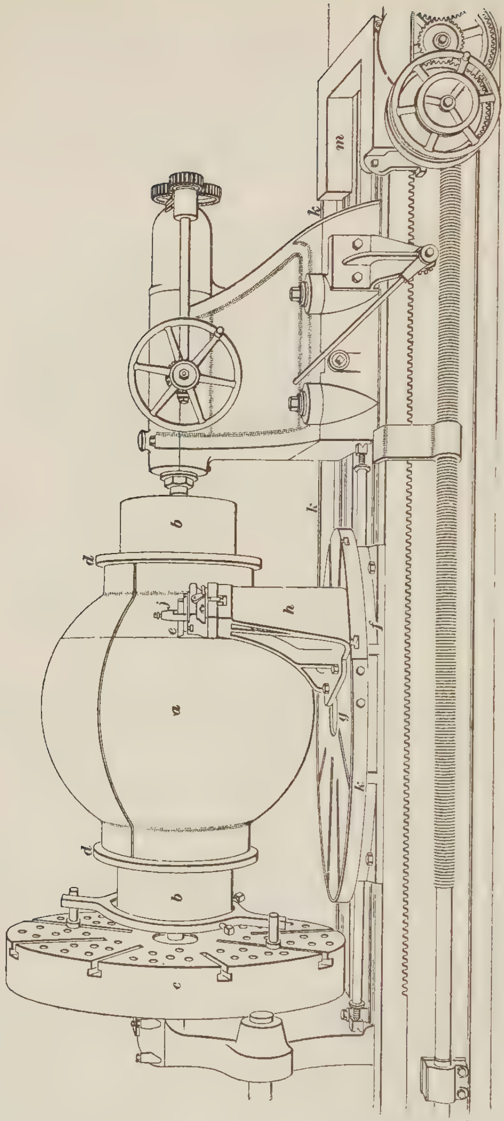


Fig. 42

45. Spherical Turning.—To turn a sphere on an engine lathe, special appliances are necessary to regulate the feed. In Fig. 42 is shown such an arrangement applied to turning a large cast-iron ball *a* for an engine bearing. The mandrel *b* is supported on the lathe centers and driven by drivers on the face plate *c*. The ball is made in sections that are clamped to the mandrel by the iron bands *d*. The tool *e* moves in a circle around the work while the work rotates with its axis as a diameter of the circle in which the tool revolves. On the stationary table *f* the rotating circular table *g* is pivoted and carries with it the upright *h* that supports the tool post *j* and the tool *e*. At *k*, on the rotating table *g*, is a wrought-iron band that is fastened by capscrews at one end to the

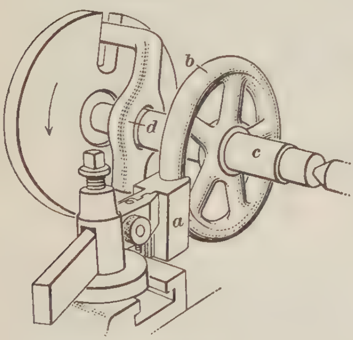


Fig. 43

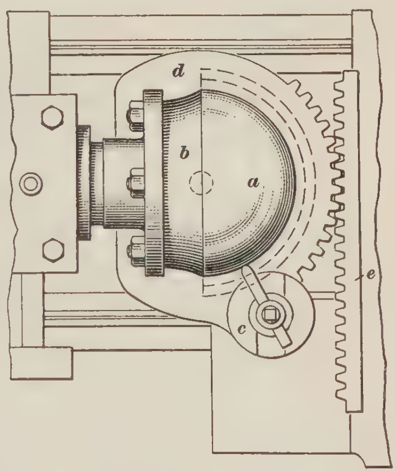


Fig. 44

table. The other end is fastened to the lathe carriage *m*, and as the lathe turns the carriage is fed away from the tailstock toward the end of the lathe, drawing with it the band *k* and thus rotating the table *g* about its axis. As the work rotates in the lathe the tool moves around it in a circular arc, so that it is always at the same distance from the point on the axis that is the center of the sphere. On smaller work, a similar method is used; but the tool is carried on a table that has a worm-wheel fastened to it and is rotated by a worm. The worm may be operated by hand or from the feed-mechanism of the lathe.

46. Turning Small Spherical Sections.—A method of turning a small circular section, not exceeding 1 inch in radius, is to use a forming tool *a*, Fig. 43. The circumference of the wheel *b* is rounded by the tool *a*, after the work has been brought nearly to shape and size by the ordinary round-nose turning tool. The wheel is mounted on a mandrel *c* and driven by a dog *d*.

47. Turning Hemispheres.—A device used in turning hemispherical surfaces is shown in Fig. 44. The work *a* is

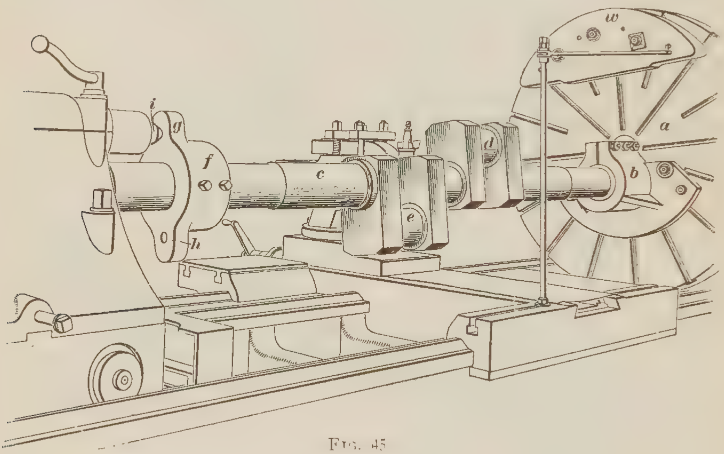


FIG. 45

mounted on a face plate *b* held on the live spindle. The tool rest *c* is part of the attachment *d*, which is pivoted on the lathe carriage, exactly under the center of the spherical work. The carriage must be clamped to the bed. The tool is made to turn the required outline of the hemisphere by means of a rack *e*, attached to the cross-slide and meshing with the teeth cut in the circular edge *d* of the device. The feed is provided by the cross-feed mechanism of the lathe. Concentric circles are scribed on the revolving base *d* as shown for the purpose of setting the tool to turn a given diameter.

48. Turning a Crank-Shaft.—One method of holding a large crank-shaft in a lathe while its crankpins are turned, is shown in Fig. 45. The crank-shaft *c* is so fastened that the

center line of the crankpin *d* coincides with the center line of the lathe spindle. The clamp *b* that holds one end of the shaft is fastened to the face plate *a*, and the clamp *f* that holds the other end of the shaft has an offset center *g* in which the dead center *i* of the lathe fits. The counterweight *w* is fastened to one side of the face plate to balance the weight of the shaft. The crankpin *d* is turned while the shaft is held in the position shown. To center the shaft so as to turn the pin *e*, the end of the shaft next the tailstock must be blocked up, the clamp *b* loosened from the shaft, and the dead center removed from the clamp *f*. The shaft is then rotated until the center *h* on the clamp *f* comes to the dead center, when the center is moved into *h* and the clamp *b* made fast to the shaft. The centers *g* and *h* on the clamp *f* hold the same relation to one another and to the shaft as do the center lines of the crankpins. When the shaft is fastened in this position, it is ready for turning the crankpin *e*.

49. Laying Out Centers for Turning Crank-Shafts. The process of locating and preparing the centers for a solid crank-shaft is illustrated in Fig. 46 (*a*) and (*b*). The crank-shaft *a* is centered, and the ends are turned to size for a short

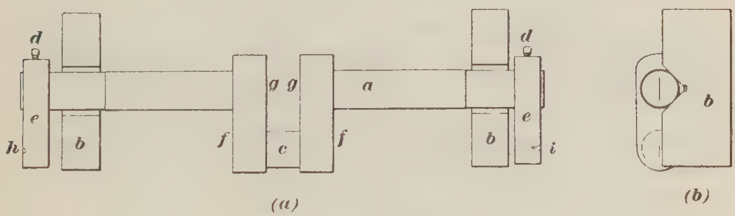


FIG. 46

distance, to receive the centering blocks *e* and to fit the **V** blocks *b*. The shaft is then placed on the **V** blocks on a surface plate and the centering blocks are fastened to the finished ends in line with the crank-arms. The centering blocks are bored to a good fit on the turned ends of the shaft, and are fastened, so that they cannot slip, by the setscrews *d*, or in some cases by keys. The center holes *h*

and i are drilled the distance from the center of the crank-shaft called for on the drawings. If the blocks are to be used many times, these center holes are usually bushed with hardened steel pieces driven in and lapped in place. The crankpin c is now set so that its center is on a level with the center of the shaft and with the centers h and i in the blocks; the blocks are made fast to the crank-shaft by means of the setscrews d.

The shaft is then ready for the lathe and all the lathe work can be completed on the shaft itself, on the crankpin, and on the crank-arms. The shaft is turned and the sides f of the crank-arms are faced when the work is on the centers in the ends of the shaft. The work is then moved to the centers for the crankpin c, which are laid off on the centering blocks e.

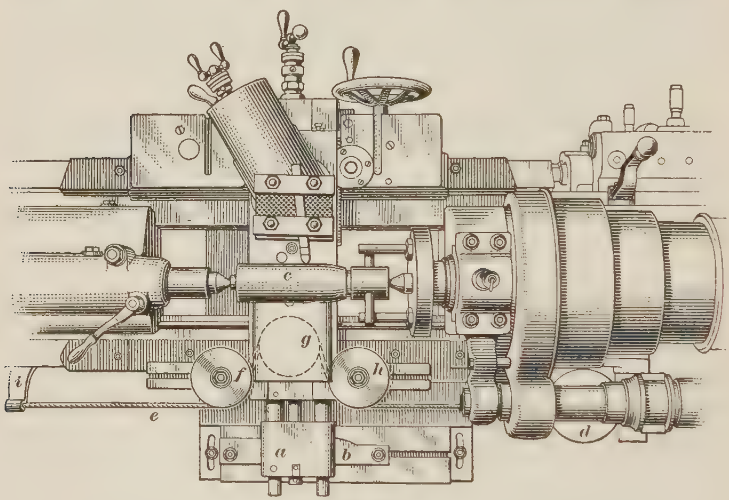


FIG. 47

The crankpin is now turned, and the sides g of the crank-arms are faced. If the crank-arms are circular disks, they may be turned on the outside with a center midway between the other two centers.

50. Turning Irregular Shapes With Forming or Profiling Attachments.—Irregular shapes of work, such as machine

handles, bottle molds, shells, steering knuckles for motor trucks and cars, etc., may be turned in the lathe by means of a templet fastened to the taper bar of the taper attachment of the lathe. In Fig. 47 is shown a profiling attachment used in the quantity production of gun shells. The cross-slide screw is first removed so as to enable the tool slide to move freely back and forth across the saddle. An extension *a* of the slide has a contact piece underneath that is made to follow the outline of the templet *b*.

The tool is kept in contact with the work *c* and reproduces thereon the shape of the templet *b* by a weight *d* suspended by a cable *e* running over the pulleys *f*, *g*, and *h*, and fastened to a bracket *i* on the lathe bed. The tension in the cable pulls the cross-slide by means of the pulley *g* toward the templet *b*. The pulleys *f* and *h* are located on the lathe bed and have fixed positions.

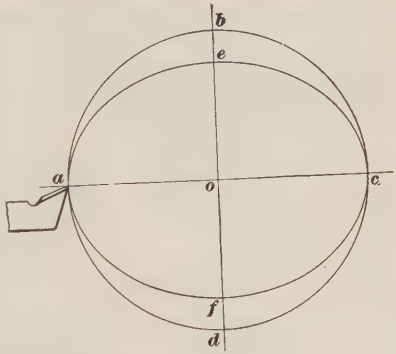


Fig. 48

51. Turning Elliptical or Oval Work.—In turning circular work in the lathe, the distance between the center of the work and the point of the tool remains constant. By referring to Fig. 48 it will be seen that if *a b c d* represents a circle with the center at *o*, and that if the tool were located at *a*, as the work revolved and *b* approached *a*, so long as the distance from the center *o* remains constant, the work would be turned to a circular form; but if by any means the center *o* could be made to approach the point *a* as the work revolves during one-quarter of a revolution, recede from it during the next quarter, advance during the third quarter, and recede during the fourth quarter, it would be possible to turn an oval. For instance, if, while the portion of the work from *a* to *b* were passing the tool at *a*, the center of the work *o* could be moved toward the tool a distance equal to *b e*, the tool would cut along the curve *a e*

of the ellipse *a e c f*. This is accomplished in a chuck for turning ovals by arranging a slide across the face plate and so adjusting the parts that the center of the work can be set a distance from the lathe center and out across the face plate.

52. Chuck for Turning Ovals.—A chuck for turning ovals is illustrated in Fig. 49 where it is shown attached to an ordinary lathe headstock. The work is secured to the plate *a* by means of bolts or clamps, or by using the threaded spindle *b*. Back of the plate *a* there are two slides *c* and *e* at right angles

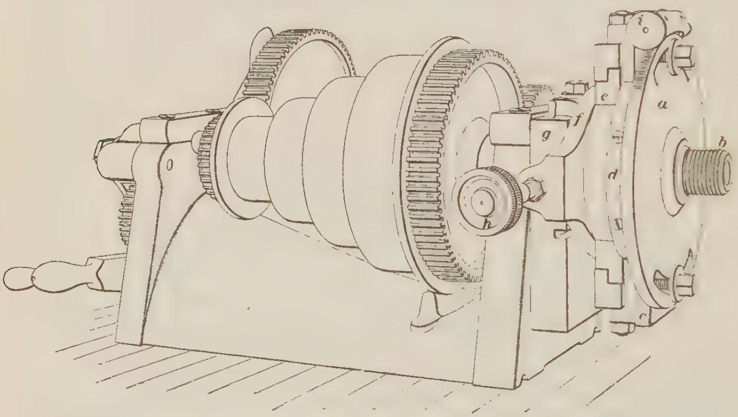


FIG. 49

to each other. The disk *d* has a long projection that reaches through and is attached to the regular lathe spindle of the headstock. The disk *d* acts as a driver for the plate *a*, the driving being done by means of the slide *c*. The slide *e* is secured by guides to the slide *c*, and is turned out on the side toward the headstock to receive a ring that is carried on the piece *f*. When the center of this ring is made to coincide with the center of the lathe spindle the center of the plate *a* and the spindle *d* rotate as in an ordinary lathe; but if the piece *f* is moved across the lathe by means of the adjusting screws, one of which is shown at *h*, the ring attached to it will force the slide *e* to travel back and forth across the

attachment as the work revolves, and this will cause the center of the plate *a*, and with it the work, to move back and forth, first away from and then toward the center of the lathe spindle proper. The result will be that an ellipse similar to that shown at *a e c f*, Fig. 48, will be turned.

53. The amount that the slide *f*, Fig. 49, is moved determines the amount of eccentricity of the ellipse; that is, the amount shown by the line *b e*, Fig. 48. The block *g*, Fig. 49, is bolted fast to the front of the headstock. In the form of chuck shown the plate *a* is provided with a screw *i*, and worm-teeth are cut for a short distance at the top of the plate. By means of these worm-teeth and the screw *i*, the plate *a* can be adjusted slightly in relation to the mechanism operating it. This device will be found very useful in resetting work in the chuck, as it serves to bring the work in line with the ellipse generated by the mechanism. This form of device is very handy for turning elliptical dies and punches, such as are used by jewelers, silversmiths, intrument makers, and the like.

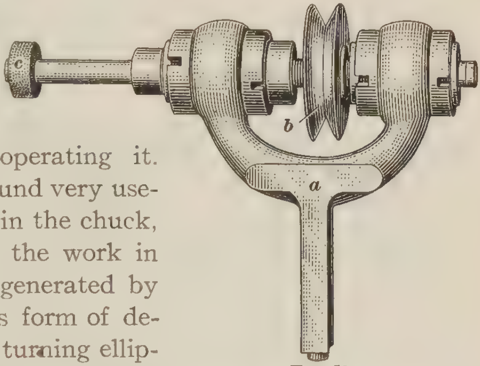


FIG. 50

54. Turning Long Shafts.—It is difficult to turn long shafts and have them remain straight, even if they have been spotted with great care to receive the steady rest. When the shaft is rolled in the process of its manufacture, its surface is more or less under tension, and, as it is turned, this tension is removed, thus allowing the shaft to spring so that the spot that was turned true when the shaft was rough is untrue after it is turned. A very light cut should first be taken and the shaft afterwards tested. If found to be untrue it should be straightened either in a press or by hammering, after which another light cut may be taken. This process is repeated until the shaft has the desired diameter.

55. Slide-Rest Tool-Post Grinding Attachment.—For light grinding operations on work held on the centers of the lathe or in the lathe chuck, the attachment shown in Fig. 50 may be used. The shank *a* fits the tool post of the compound rest of the lathe and the attachment can thus be set in almost any position for grinding in difficult places. A round, twisted leather belt is run over the wheel *b* to drive the grinding wheel *c*. Besides grinding operations, the attachment may be used for other purposes, such as light milling and drilling, by substituting suitable tools for the grinding wheel *c*.

56. Blocking Up of Lathes.—When the work to be operated on is too large to be swung in the largest lathe, the

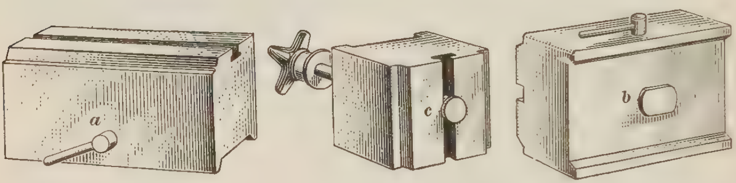


FIG. 51

headstock, tailstock, and tool rest are sometimes blocked up by putting iron blocks under them, until the lathe centers are sufficiently high above the bed to allow the work to swing. In Fig. 51 these blocks are illustrated. The two blocks *a* and *b* are planed on the bottom to fit the bed and on the top they are made to fit the bases of the head and tailstocks, whereas the small block *c* is clamped in the groove of the cross-slide of the carriage, underneath the compound rest. When screw cutting is to be done with the raising blocks in place, the rocker on the headstock has to be made longer to carry an extra large intermediate gear since the stud and the lead screw are necessarily farther apart then before.

The gap lathe is intended to replace the need of a blocked-up lathe. In Fig. 52 is shown a flywheel of large diameter being bored in a gap lathe. The swing of the lathe has been further increased by the use of the raising block *a*,

and the tool is elevated by an equal block *b*. In case the tail center must be used then it, too, must be raised by a block *c*.

FINISHING LATHE WORK

FILING AND SCRAPING

57. Files for Lathe Work.—Lathe work that is to be polished should be finished with a very smooth finishing cut, after which it may be made smooth by filing, or, if it is cast

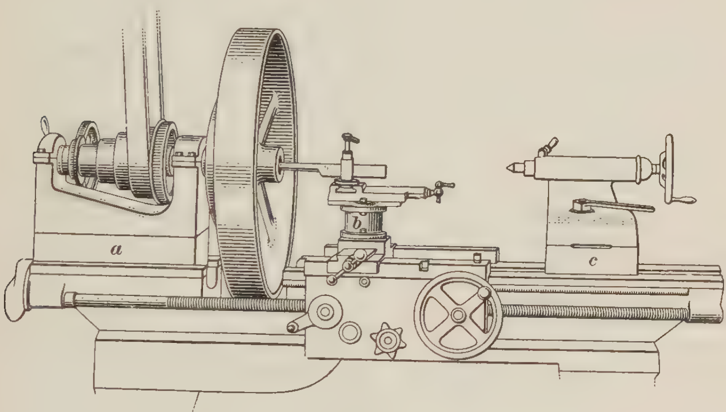


FIG. 52

iron, by scraping. Just enough filing or scraping is done to remove the tool marks. The files used for this purpose are suitable sizes of smooth and dead-smooth double-cut files, single-cut mill files, and circular-cut files of the finer grades.

58. Care of Files.—The file selected for filing lathe work should be examined to see that the spaces between the teeth are clear and free from *pins*, which are small bodies of iron or steel that have been torn from the stock being filed and have become wedged tightly between the teeth. If the file is dirty, a file card or brush having fine wires instead of bristles, is used to remove the dirt by brushing vigorously crosswise in the direction of the teeth. If the file card fails to remove any

pins that may be in the file, they must be picked out separately with the point of a scriber or a similar sharp tool. A piece of sheet brass or copper 3 or 4 inches long and from $\frac{1}{2}$ to $\frac{3}{4}$ inch wide may be used very effectively to remove dirt or pins by pushing it crosswise along the file teeth. The file teeth cut shallow grooves in the soft metal and the teeth so formed remove most of the dirt and pins. The file is then oiled evenly on both sides, usually with machine oil, and wiped fairly dry with waste. Some workmen omit the oil and simply rub the whole of the cutting surfaces with chalk to prevent metal from sticking between the teeth.

59. Speed of Work for Filing.—The work to be filed in a lathe should be run at a speed about double that used for turning with carbon-steel tools, or somewhat more. However, if the file is brought against a piece revolving at an excessive speed the points of the teeth are soon worn away. When the work is small in diameter, it may be run at quite a high number of revolutions, so that in making one stroke of the file, the work will make a number of revolutions. This action is desirable when an attempt is being made to keep the work true. It is difficult to file the same amount from every point along the work, because one part of the work will be filed more than another, with the result that the longer the filing operation is continued, the more untrue the work becomes.

60. Even Filing.—When the work is large in diameter, it will be necessary to run it at a lower number of revolutions per minute. Suppose that the rate of file strokes is one a second, and the rate of revolutions of the work the same. Then, for one stroke of the file forwards, the work will make half a revolution, and it will be filed half around its circumference. While the file is being drawn back for the second stroke, the work begins its second revolution, and the file again cuts half of the circumference of the work. It will also be on the same side of the work. In this case, the file has cut twice on one side of the work, and has entirely skipped the opposite side. This will be continued as long as the rate of file strokes and revolutions of the work are the same. It may be seen from this

that to keep the work nearly true, the file strokes should be slow enough to allow the work to make a number of revolutions for each stroke of the file. If the work is large, like a pulley, the file is held nearly stationary as the work revolves and just enough forward movement is given to avoid bringing all of the wear in one place on the file. If wrought iron or steel is being filed in the lathe and the workman finds the file filling up, he rubs his thumb and finger over the flat sides of the file to loosen the filings and raps the edge of the file lightly on the shank of a tool held in the tool post to jar the filings out. If they till stick tightly, he uses the file card.

61. Position of File.—In filing, the point of the file should be held to the right so that it is at an angle to the work, as shown in Fig. 53. While held in this position, the file is moved squarely across the work, as shown by the arrow, although it appears as if it were moving toward the left. The file is held in this angular position so that its teeth, shown by the dotted lines, will take a shearing cut on the cylindrical surface, which prevents chattering and the forming of pins in the file. The workman changes the angle of the file according to judgment, guided by his sense of feeling. If the file has a tendency to chatter, he changes the angle until it cuts smoothly. The circular-cut file, however, works best when held and moved squarely across the work; at the same time a slight horizontal circular movement is given to the elbow of the arm holding the file handle.

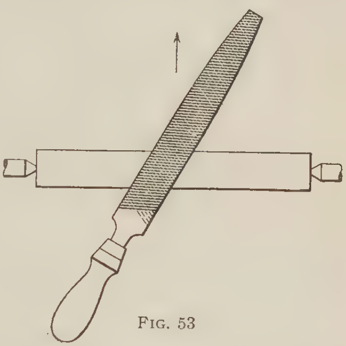


FIG. 53

62. Scraping Turned Cast-Iron Surfaces.—Cast-iron turned surfaces are prepared for polishing by filing on the lathe, if it is possible to do so. If not, they are scraped with a hand tool. Such a tool may be made from a worn-out flat

file, and may be made any convenient size and shape. Scraping in the lathe is done by clamping a tool in the tool post so that its shank will be close to and parallel with the surface of the work. The work is speeded about the same as for filing and the hand tool is rested on the tool and brought lightly in contact with the work. The hand tool is then moved along the rest to remove a slight thickness of metal. This process is repeated until the surface is as smooth as required. Very smooth work may be produced in this way, after a little practice.

POLISHING

63. Use of Emery Cloth.—After the tool marks have been removed by filing or scraping, the piece is treated with a coarse emery cloth, No. 60 well oiled, which will remove the file marks, after which a fine grade of emery is used until the coarser emery marks have been removed. Then finer grades, as Nos. 80 and 100, are used until the desired polish is obtained. Emery cloth should be pressed quite hard against the work by a polishing stick, which is passed over the tool rest of the lathe and under the work, the emery cloth being held between the stick and the work. By pressing down on the outer end of the stick, the emery cloth can be brought with sufficient pressure against the work. The stick should be so handled that the emery cloth will move back and forth on the work in such a way that the lines cut by the particles of emery will be constantly crossing and recrossing one another. Oil should be supplied to both the work and the emery, in a quantity sufficient to keep the surface moistened, but not in such excess that it will be thrown from the machine.

64. The numbers representing the grades of coarseness of emery cloth run from 8 to 120, corresponding to the grain number of loose emery. The degree of smoothness of surface they leave may be compared to that left by files as follows:

Nos. 8 and 10 represent the cut of a wood rasp.
Nos. 16 and 20 represent the cut of a coarse rough file.
Nos. 24 and 30 represent the cut of an ordinary rough file.

Nos. 36 and 40 represent the cut of a bastard file.
Nos. 46 and 60 represent the cut of a second-cut file.
Nos. 70 and 80 represent the cut of a smooth file.
Nos. 90 and 100 represent the cut of a superfine file.
Nos. 120F and FF represent the cut of a dead-smooth file.

65. Speed for Polishing.—A higher speed is used for polishing than for filing. The higher the speed the better, provided the work and the machine are balanced so that the high speed does not shake the machine too much.

66. Care of Centers When Polishing.—When a piece of work is being polished, enough heat may be generated to cause it to expand along its entire length. If, in the first place, the dead center has been made fairly tight, it will cut and stick in the end of the work, the oil having been burned out, and may be twisted off. This should be carefully guarded against by keeping the centers free and well-oiled.

67. Finishing Polished Surface.—When the piece is nearly finished, the pressure of the emery is reduced and the movement along the length of the work is slower. For the finest grades of polish, fine crocus cloth is used and still finer polishes are produced by employing rottenstone. Not much lathe work is carried to the perfection of polish that requires crocus cloth or rottenstone for finishing. A very high polish may be obtained by using a much worn piece of No. 100 emery cloth. Grain emery is often used on the speed lathe in the place of emery cloth; but this should be done only on a lathe used exclusively for polishing. Bare wood, or pieces of lead on the face of the wood, is used to hold the emery against the work. The particles of emery are embedded in the soft wood or in the lead, and so are held from being thrown from the work. Oil is used as before. If the use of loose emery is necessary, the **V**'s and bearings of the engine lathe should be well covered, as they will be injured by the emery.

If the work has been carefully filed, a good polish can be obtained with Nos. 60 and 90 cloth, and a brilliant polish by finishing with No. 120 and flour emery.

68. Polishing Clamp.—For plain cylindrical work, a very convenient and effective way of holding the emery or other abrasive against the work is brought about by fastening two pieces of wood together at the end with a leather hinge. The two inside faces of the pieces are cut out at a short distance from the hinged end, so that they will fit over the shaft, as shown in Fig. 54. By pressing the outer ends together, con-

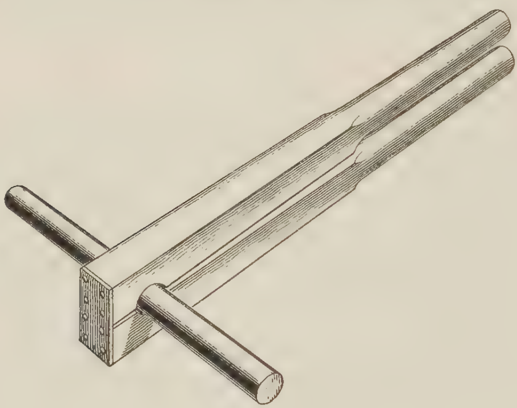


FIG. 54

siderable pressure is brought against the shaft. Either emery cloth or grain emery may be used with this device.

69. Finishing by Grinding.—Most cylindrical parts may be finished more quickly and accurately in the grinder than in the lathe and many classes of work are, at the present time, simply rough-turned in the lathe and then ground to size in a grinding machine, or they may be finished entirely by grinding, the lathe not being used.

LUBRICANTS AND COOLANTS IN LATHE OPERATIONS

METHODS OF LUBRICATION USED IN PRACTICE

70. Heating Effect of Turning.—Cutting the metal and bending the shaving by the lathe tool produces considerable heat. The amount of this heat depends upon the shape and condition of the tool, the size and kind of material being cut, and the speed. The larger the work the more time there is for the heat from the cutting action to disappear before the same part of the work comes around again to the tool. Therefore, the larger the diameter of the piece being turned the higher the cutting speed may be. A soft and easily bent metal like copper causes less heat when turned than does a hard and tough steel. The tool gets hotter than the work because the tool is constantly cutting the material and curling the shaving. A thin sharp tool cuts easier than a thick, or blunt, one, and generates less heat on this account. On the other hand, the thin tool must be used on light cuts, as the heavy pressure will soon destroy the tool. The tool must be blunt enough to back up the cutting edge and give it strength and endurance. Whatever the metal being turned, the speed must be slow enough to give the heat time to dissipate, otherwise the tool will become overheated and lose its ability to cut.

71. Properties of Lubricants and Coolants.—*Lubricants* are used in lathe operations to make the cutting easier by decreasing the friction between the chip and the cutting tool. *Coolants* are liquids poured over the point of the cutting tool and the chip to prevent the tool from getting so hot that its temper will be drawn, while taking the heaviest cuts and operating at the highest speeds that the lathe will stand. Some coolants have more or less lubricating qualities, but their chief aim is to keep the tool with a fair factor of safety below the temperature at which it will fail. This temperature is about 600° F. for the ordinary carbon steels and about 1,200° F. for the high speed steels. Coolants assist in dissipating the

heat generated by the cutting process by forming a film or coating of liquid between the chip and the tool and in so doing prevent a direct conduction of heat from chip to tool. The coolant loses the heat from itself while being carried around in the circulating system of the machine.

72. Stream Lubrication.—It has been observed that by using as large a stream of coolant as is practicable on the chip at the point where it is being removed by the tool, the cutting speed for high-speed tools can be increased as much as 40 per cent. Automatic screw machines are frequently designed with this form of stream lubrication; they are equipped with an arrangement of shields whereby the cutting tool is surrounded entirely or for a large portion of its circumference by a coolant, which is constantly renewed.

73. Circulating Lubricating Systems.—Turret lathes and automatic machines are generally equipped with a pump and piping to supply a continuous stream of coolant, such as lard oil, on the tool. Engine lathes are rarely furnished with such equipment, lubrication usually being done by hand or by means of an oil reservoir with long spout, fastened onto and traveling with the tool rest.

74. Influence of Cut, Material, Speed, and Feed on the Selection of the Proper Lubricant.—The kind of material that is used in cutting operations has an important bearing on the selection of the cutting oil. *Tough* material, such as wrought iron, forms a chip that peels off in a long, curly ribbon that bears and rubs on the nose of the cutting tool for the whole period of cutting. Such material requires the very best lubricating oil. In *brittle* material, such as cast iron, the chips break off in a granular form with little or no rubbing on the nose of the tool. Even at high speeds and coarse feeds a coolant will be all that is required. Very *hard* materials such as carbon steel, form chips that bear on the nose of the tool for short distance and then break off in small pieces. Hence, a straight mineral oil with both lubricating and cooling

properties, is desirable for such material. In cutting very *soft* material, such as copper, a chip is rolled off in a ragged ribbon that may or may not curl up. Rubbing of the chip on the nose of the tool covers a large area but its pressure is not great.

75. In general, when the chips bear on the tool with heavy pressures a straight mineral oil compounded with various amounts of animal or vegetable oils should be used to form a tough film to resist those pressures. Where maximum cooling is required and it is important to flush away the chips, with lubrication as second consideration, a mineral oil compounded with animal or vegetable oils and saponified so as to be readily soluble in water should be used. Copious applications of such coolants will absorb and conduct away the heat generated.

LUBRICANTS AND COOLANTS USED IN PRACTICE

76. Composition of Lubricants and Coolants.—Mineral oils do not carry off the heat as well as the animal or vegetable oils, such as *lard oil*, *fish oil*, *olive oil*, etc., but their lubricating qualities are much higher. Water is a fine coolant but has no lubricating value and it is liable to rust both the work and the machine. Lard oil appears to be the best compromise and is, therefore, most widely used in operations on engine lathes as well as on turret or automatic machines. It has fair qualities as a coolant and for light cuts it has sufficient lubricating value. It should always be kept thin and preferably used on the same lathe for the same material, as changing, for instance, from copper to steel work decidedly affects its lubricating qualities. As lard oil is expensive, cottonseed oil and other cheaper liquids are generally mixed with it. Lubricants and coolants specially prepared for almost all purposes can be bought.

77. When water is used as coolant it is often mixed with soda or soap to prevent corrosion of the tool and work. So-called cutting compounds are sometimes effectively used by dissolving them in water, giving a slight lubricating quality to

the solution. A mixture of sal-soda, water, and enough lard oil or soft soap to thicken the mixture somewhat, makes a good coolant. Where a cheap coolant is required use 1 pound of sal-soda, 1 quart of lard oil, 1 quart of soft soap, and enough water to make 10 or 12 gallons. The mixture is first boiled for $\frac{1}{2}$ hour by passing a steam coil through it, and then 2 pounds of unslaked lime are added to prevent any objectionable odor.

78. *Cast iron* is usually machined dry, although by using a coolant the cutting speed may be increased considerably. However, the dirt caused by the fine chips mixed with the liquid is very objectionable. For tapping in cast iron, a mixture of 40 gallons of water, 10 gallons of lard oil, $2\frac{1}{2}$ pounds of soda ash, and 10 ounces of borax makes a good non-corrosive coolant.

Brass and *bronze* require no coolant when the cuts are light. *Babbitt* may be machined dry; sometimes a mixture of kerosene and turpentine is used to prevent the formation of balls of metal on the cutting tool.

For machining *copper*, milk may be used, or a mixture of lard oil and turpentine. For *aluminum*, kerosene is used. When for reasons of fire danger this liquid cannot be used, a mixture of 40 gallons of water, 10 gallons of lard oil, and $2\frac{1}{2}$ pounds of soda ash may be used. For turning and threading operations on *steel*, a mixture of equal amounts of lard oil and paraffin oil is often used, the paraffin being added to lessen the cost. If water alone is used, the peculiarly bright surface, known as *water cut*, is obtained.

79. Changing Lubricants on Lathe Work.—For duplicate lathe operations requiring very fine tolerances, it is not advisable to change the lubricant during operations. It has been observed that a change in lubricant affects the size of the diameter of the work somewhat. Where the tolerance in some cases equals one-half thousandth of an inch, this change may be sufficient to cause rejection of the work.

ERRORS IN LATHE WORK

CAUSES OF ERROR

80. Chances for error in turning cylindrical work on the lathe are numerous. If any of the causes for error are present the work may be out of round owing to uneven depth of cut, or the diameter of the work may differ in different places along the work, etc. Error in cylindrical turning may be caused by spring of the work, or inaccurate adjustment of the machine.

SPRING OF LATHE TOOLS

81. Causes.—The amount that the tool will spring depends on the position it holds in relation to the work; on the rigidity of the tool; on the closeness of fit between the tool block and the slide; on the stiffness of the shank of the tool; and on the shape of the tool.

82. Position of Lathe Tool.—When the point of a tool is set above the center of the work, as it bends in its shank the point tends to follow in an arc of a circle drawn about the bending point. If this arc cuts into the work, the tool, following in that path, will spring deeper into the work. If the tool is so located that when it bends or springs the arc moves away from the work, then the tool will spring away from the work. It would therefore seem that the best place to set the point of the tool would be level with the center, so that, if the tool springs, it will not spring into the work. A tool properly shaped for this position would have very little front rake and its keenness would be given entirely by increasing the angle of top rake. Such a tool is absolutely required for taper turning, because the tool must be at the height of the center to turn a true taper; but for ordinary turning other conditions arise, making it objectionable. When this tool is used, the total force acting on it is in a direction tangent to the diameter of the work at the point of the tool.

83. When a tool without front rake is used, the force will be directly down, or perpendicular to the top of the lathe bed, in the direction of the arrow DC, Fig. 55 (a). As increased front rake is given to the tool and it is set higher on the work, the line of force changes its direction, so that if the front rake is 30°, the force acting against the point of the tool at O' will be in the direction of the arrow BA. When the force on the tool is in the direction of the arrow BA, it tends to force the tool block back from the work; this causes some pressure on the cross-feed screw. If the tool had still more front rake and were set higher, the pressure on the cross-feed screw would increase; and if the tool could be set as high as the point O'', the force of the cut would be in the direction of the line FE, which would be entirely against the cross-feed-screw. This pressure against the cross-feed screw is very desirable. It holds the tool block back and takes up the lost motion that may be in the screw, so that, when an adjustment is being made, any turn of the screw to the right at once acts in moving the tool block toward the work. It also allows the tool to be held in such a position that there is little danger that the pressure of the shaving on the top face of the tool will pull the tool and tool block forwards, thus taking up the lost motion in the cross-feed screw.

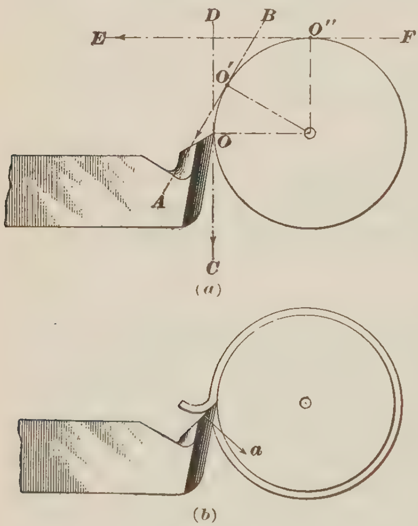


Fig. 55

84. From Fig. 55 (b) will be seen that when a tool is set at the center and ground with much top rake, the pressure of the shaving on the top face is in the direction of the arrow a. This direction is so nearly parallel to the line of the cross-slide

that, if the slide is loose or the screw has lost motion, the tool will tend to slide into the cut. If the tool is set higher, this force on the top face is in the direction shown in Fig. 56 and there is little tendency to drag the tool into the cut. Practice, therefore, has settled on tools with a fair amount of front rake, which allows them to be set above the center of the work, and gives the desired pressure against the cross-feed screw.

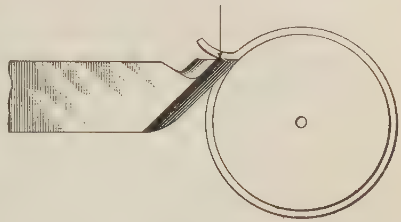


FIG. 56

85. Variations in Depth of Cut.—If, in turning a piece, an attempt is made to finish the work very close to size with one roughing cut, leaving a very slight amount for the finishing cut, the following results may ensue: The tool is started and the cut taken for a short distance, and by a series of fine cuts the work is brought to the desired diameter shown at *a*, Fig. 57. The feed is thrown in and soon the tool starts in the heavy cut.

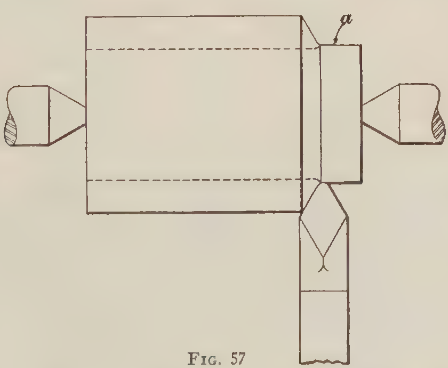


FIG. 57

As soon as the heavy pressure comes on the tool, it springs and takes a still heavier cut. The piece is thus turned smaller in diameter, as shown by the dotted lines, and in many cases may be made below the desired size. This is one reason why at least $\frac{1}{64}$ inch should be left for finishing.

86. In another case, a casting or a forging has a large lump on one side, as in Fig. 58, and this must be turned off. Because of the form of the work, the shaving will be of different thicknesses, and consequently there will be different pressures on the tool, which will thus be caused to spring to various depths, with the result that the piece will be neither round nor true, and that a second finishing cut will be necessary.

87. Reducing Error Due to Spring of Tool.—The possibilities of error due to the springing of the tool are guarded against by using tools with heavy shanks, by clamping the tools very close to the cutting edge, and by adjusting the tool block so that there is no lost motion in the slide. With these precautions, work may be performed, so far as the tool is concerned, with sufficient accuracy for all ordinary machine construction. In discussing the spring of the tool, it has been assumed that the work was very rigid, so that all the spring occurred in the tool. The tool, however, must not be held responsible for all error, as much of it may be caused by the spring of the work and of the machine.

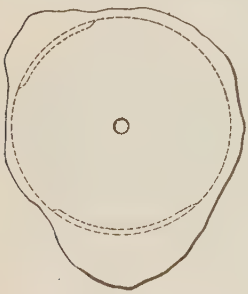


FIG. 58

SPRING OF THE WORK

88. Effect of Weight of Work on Spring.—Any action that may cause the work to bend or deflect so that its axis is not a straight line will cause the work to be untrue. If the piece is short, and its diameter great, the spring is less than when the work is long and slender. In long pieces, the weight of the piece between the center is sufficient to demand attention.

89. Effect of Force of Cut on Spring.—The force required to turn a shaving acts against the tool, tending to spring it down, and reacts in the opposite direction, tending to bend or spring the work up. When the tool is starting at the end of the work, there is less deflection than when it has reached

the center. If a bar is supported at the two ends and a load is applied at the center, it will deflect more than if the load is applied very near the ends. Because of this great deflection at the center of the work, the tool cannot cut so deeply; consequently, the work, when turned, will be larger at the center than at the ends. This error must be corrected by taking very light finishing cuts, or, in the case of long slender pieces, the work must be supported by the use of steady rests.

SPRING DUE TO METHOD OF DRIVING

90. Action of Bent-Tail Dog in Springing Work.—The ordinary bent-tail dog produces a variety of strains in the work, some of which are constant and some variable. All, however,

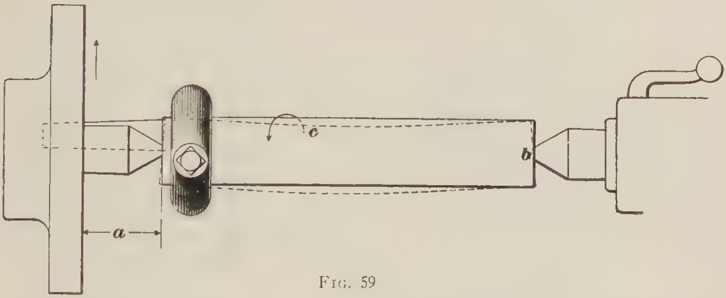


FIG. 59

tend to distort the work. These forces may be considered separately. First, there is a leverage from the point of the live center. The amount of this leverage depends on the length of the live center. This is shown in Fig. 59 which represents a side view of a piece of work between the centers. The tail of the dog is at the back of the machine. Suppose the tailstock end *b* of the piece to be clamped rigidly so that it cannot turn. If power is applied to the lathe the work will tend to turn toward the operator in the direction of the arrow *c*; but as it cannot, the piece is put under such a strain that it springs. The leverage is represented by the distance *a* that the lathe center projects beyond the face plate. The force of the face plate, which tends to lift the tail of the lathe dog, acts from the point of the center as a fulcrum and tends to bend

the work down, as shown by the dotted lines. If the lathe center were longer, there would be a greater force tending to spring the work because of the increased length of leverage *a*.

91. Effect of Position of Tool.—When the tool begins to cut at the end *b*, Fig. 59, the resistance of the cut at this point acts the same as if the work were clamped at this end as just described. The effect is the same, though not so great as clamping the end; for with a tool the strain can never be greater than that required to cut the shaving. As the tool feeds along, this resisting point approaches the point of the live center or the fulcrum from which the work bends. The result is that the amount of spring of the work will change. There is thus a changing force tending to spring the work; this force depends on the position of the tool along the work

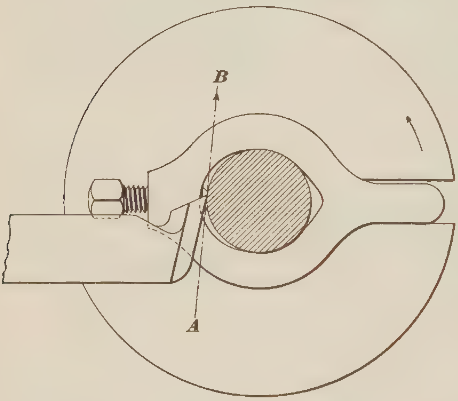


Fig. 60

92. Suppose that, in another case, the tool is cutting in a position midway along the length of the work. A section through the work is taken at this point, as shown in Fig. 60. This shows the tool at the front with the tail of the dog diametrically opposite. As the work revolves toward the operator in the direction of the arrow, the force required to turn the shaving is made with an upward pressure of the tool, which tends to spring the work up in the direction of the arrow *A B*. The force required to revolve the work tends to spring the work down, as the dog is at the back of the lathe, and the forces act as shown in Fig. 59. In this case, there are two forces tending to spring the work in opposite directions and to balance each other; namely, the force of the cut and the pressure on the lathe dog

93. When the work makes half a revolution so that the tail of the dog is at the front, as in Fig. 61, the force of the cut will act in an upward direction AB as before; but the pressure on the tail of the dog will now be in the same direction. Hence, there will be two forces, both tending to spring the work up. In the first case, it is the difference of the forces that tends to spring the work. In the second case, the sum of the forces acts to spring the work up. Here, again, because of the varying forces, various degrees of deflection occur.

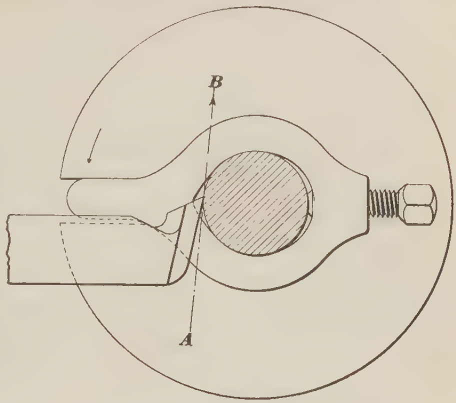


Fig. 61

When a straight-tailed dog and a driving pin, as shown in Fig. 62 are used, the conditions are reversed, the effect of the leverage of the bent-tailed dog being entirely eliminated, so that when the dog is at the back, both forces tend to spring the work up, and when the dog is at the front, the two forces are opposite and tend to balance each other.

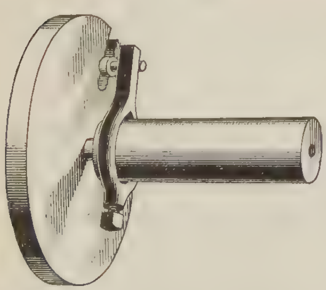


Fig. 62

CORRECT METHOD OF DRIVING

94. Straight-Tailed Dogs. Fortunately, the complicated strains arising from the ordinary methods of driving the work may be eliminated by changing the driving devices. The distortion shown in Fig. 59 may be remedied by using a straight-tailed dog and a driving pin in the face plate, as shown in Fig. 62. A joint is thus obtained between the pin and the dog, which breaks the leverage a, Fig. 59, and so eliminates the bending strain.

95. The variable forces represented in Figs. 60 and 61 may be balanced by using a two-tailed dog and two driving pins in the face plate, as shown by Fig. 63. When the work is thus driven, the two forces at the ends of the dog balance each other, and the only force remaining that tends to spring the work is the upward force of the tool.

96. Great care is necessary in adjusting the driving pins in the face plate so that the same pressure will be brought against each pin. In some instances this may be accomplished by moving one of the pins in the slot of the face plate in or out from the center. As the tail of the dog and the slots in the face plate are not parallel, moving the pin toward the center will bring it against the dog, and moving it from the center

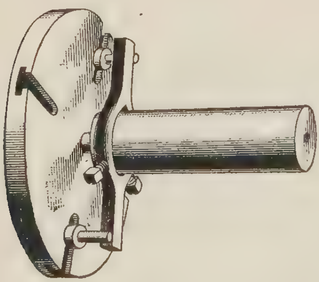


Fig. 63

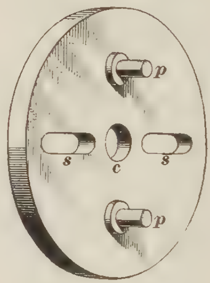


Fig. 64

will move it away from the dog. In this way the pressure on the pins may be equalized.

97. Use of Equalizer.—A very convenient and successful method of equalizing the pressure on the pins when the two-tailed dog is used, is by means of the equalizer or driver shown in Fig. 64. This consists of a plate carrying the driving pins *p*. The plate is fastened loosely to the front face of the face plate by means of bolts or studs screwed solidly into the face plate but fitting loosely in the long slots *s* in the driver. The studs keep the driver from slipping around on the face plate, but give it freedom to move a distance along the slots equal to their length. Suppose, in use, the greater pressure of the dog first comes against the top pin. The pressure would

force the entire driver back, which would slide the lower pin up to the dog. As soon as the pressures balanced each other, the plate would stop sliding and continue to keep up the equilibrium.

ERRORS IN LATHES

98. Poor Adjustment.—Imperfect work may often be traced to the poor adjustment of the machine or to the fact that the machine is much worn. When the lathe is in this last condition, it will be noticed that the spindle is slightly out of line with the bed and that it will neither bore holes straight nor face surfaces true. A great deal of wear comes on the lathe bed at a part quite near the headstock, because the greater part of the work turned on the lathe is short, and the carriage moves over this part more than over any other. If the gibs that hold the carriage to the bed are so adjusted that the carriage is in good adjustment at this worn place, it will be found that when longer work is to be turned, the carriage will not slide easily along the unworn part of the bed.

99. Necessity for True Centers.—The live center should always run true. The dead center should be truly conical and smooth. If a live center were out of true, or eccentric, so that its point wabbled slightly and a piece of work were turned on it, the work might be round and straight, but the turned part would not be true with the center hole. A piece may be turned to various diameters and shapes on untrue centers and the different cuts may all run true with each other, provided they were all taken at one setting. If, however, the dog had been loosened and a half turn given to the work, the dog being again clamped, the piece just turned would run out of true an amount double the error of the live center. When, therefore, a piece is partly finished on one machine and then taken to another for final finishing, it is necessary that the centers be true on each machine. If the second workman finds that the outside of the work does not run true, he should make sure that the centers of his lathe are true; if such is the case, the center holes should be scraped until the turned part runs true on the dead centers.

100. Scraping Center Holes.—If the circumference of the work is found to be out of true with the center holes, the holes may be brought true with the work by scraping. Center holes are scraped after first cleaning both lathe centers and work centers. The work is then placed on centers without putting a dog on it. A parting tool is clamped in the tool post, as for cutting, but preferably with a piece of white paper or card laid below the tool. The tool is then run up to the work near one end and the work is revolved backwards past the tool point by one hand while the tool is fed up to the work with the other. By looking through between the work and the tool any eccentricity is easily seen over the white paper. The high side is chalked, the piece is taken from the lathe and gripped in the vise, as shown in Fig. 65, with the high side down, so that the side of the hole to be scraped will be nearly horizontal.

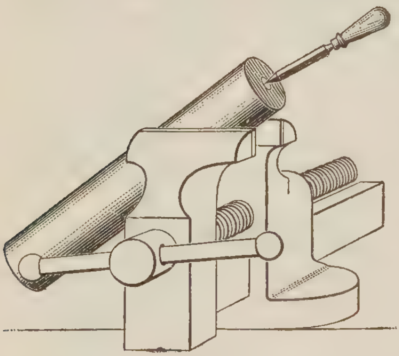
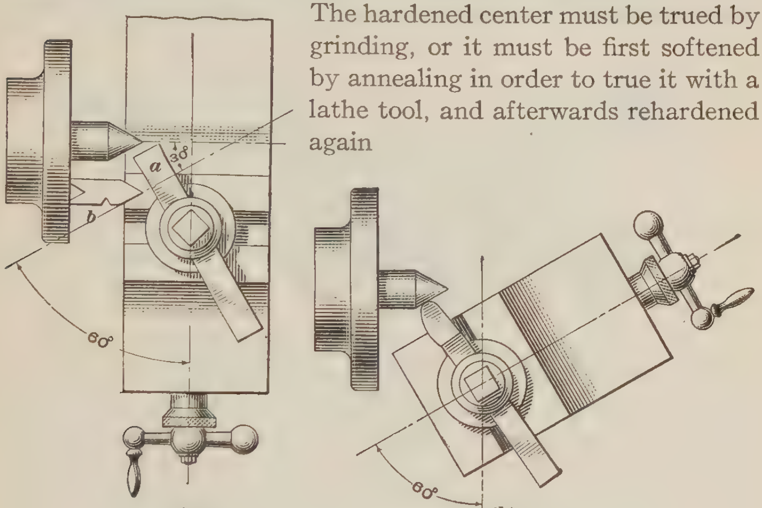


FIG. 65

101. The three-cornered scraper is placed in the hole with two of its edges in contact with the hole and pressure is brought on it with both hands, so that one edge is in more intimate contact with the surface of the hole than the other. This action determines which is the cutting edge. The scraper is rotated slightly and may be moved to cut either toward or away from the operator. The scraping is started at the middle of the untrue part, where the most metal is to be removed, and is reduced in both directions to keep the hole round. The work is then returned to the lathe, tested as before, and the operation of scraping continued until the outside surface runs true at both ends. Care should be taken that the scraping is done so that the completed surface of the hole will show a good bearing on the lathe center. Center holes are ground readily by a special device held in the tool post.

102. Treatment of Lathe Centers.—Lathe centers are made of carbon tool steel. To reduce the amount of wear on the points of the centers, they should be hardened, which is done by heating the centers to a dark red and cooling them quickly by immersing vertically in water or oil. As the live center is located in the headstock spindle and revolves with the work, it is subjected to much less wear than the tailstock, or dead, center, which is stationary with respect to the work. Therefore, the live center is not always hardened. In some cases it is left soft so that it can be trued with a lathe tool. The hardened center must be trued by grinding, or it must be first softened by annealing in order to true it with a lathe tool, and afterwards rehardened again



(a) (b)

Fig. 66

103. To anneal a hard center, it should be heated slowly and evenly to a dark-red color. Then it is cooled off very slowly, which is best done by cooling down overnight in the furnace or by packing it in dry ashes or lime for several hours. A quick anneal is sometimes made by cooling the dark-red center in air until it will not smoke or char a dry pine stick. Then the cooling is quickly finished in water.

104. Truing Lathe Centers by Turning.—A lathe having no compound rest may be used for turning the live center true by clamping in the tool post a broad-nosed tool *a*, Fig. 66 (*a*),

having its edge ground perfectly straight. The cutting edge is set to an angle of 30° with the center axis by adjusting it to a center gauge held with its open end against the face plate, as shown at *b*. The lathe is speeded up and three or four light forming cuts are taken from the center, starting at the point. Care should be observed, when the last cut at the large diameter is taken, that the tool does not catch as the whole length of cutting edge begins to cut, for this is liable to spoil both center and tool. The finishing cut should very lightly scrape the center and leave it true. It is then filed lightly with a smooth or dead-smooth file and polished with emery cloth. If the lathe

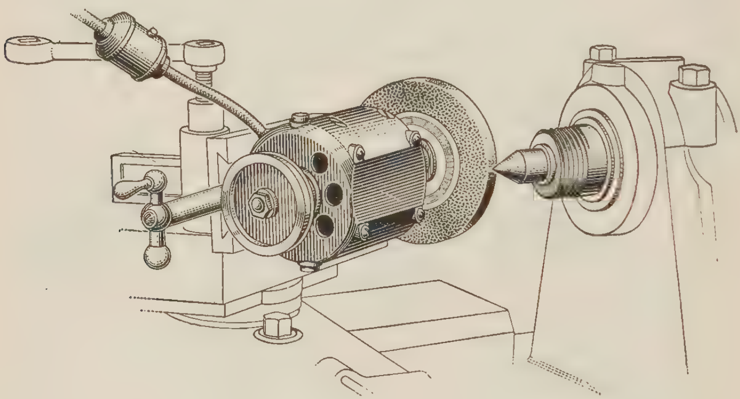


FIG. 67

has a compound rest, the rest is set to the required angle and an ordinary turning tool clamped in the tool post as shown in (*b*). A light cut is taken over the center, which is afterwards filed and polished.

105. Truing Lathe Centers by Grinding.—A small electrical grinding machine clamped in the tool post of the lathe, and set at an angle of 30° with the line of centers, as shown in Fig. 67, may be used to true the centers. The wheel is moved back and forth along the angle of the lathe center by the feed-screw in the base of the motor, while the lathe center revolves slowly. The surface of the center should move opposite to

to that of the wheel in contact with it. The machine may be connected to any ordinary electric-light socket.

106. When both centers are to be trued, the dead center should be trued first. It is put in the place of the live center, and there ground smooth and true. It is well to polish the dead center with emery cloth and oil.

Stationary grinding machines are also used for truing dead centers rapidly and accurately. But as these centers do not always run true when placed in the lathe, the method of grinding them while they are located in the lathe spindle is often preferred.

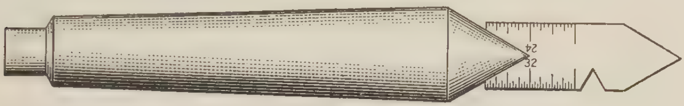


FIG. 68

In truing lathe centers their angle should be tested from time to time by applying the 60° center gauge, as shown in Fig. 68.

107. Cleaning Center Hole.—Before grinding or truing a lathe center, great care should be taken that the center hole in the spindle is very clean before the center is put in place. If any dirt or small chips collect between the center and the hole, they will hold the center away at that point and make an incorrect fit. The center might be trued while in this position, but upon removal of the dirt it would at once run untrue.

It is best to plug the hole with waste to keep out the dirt, as it is very difficult to remove dirt from the hole. Use a stick with a small piece of rag wound around it to wipe out the hole. *Never put your finger in the hole while the spindle is running*, in an attempt to wipe out the dirt. There is great danger of the finger getting caught and being severely injured.

108. Removal and Marking of Live Center.—After a live center has been ground true in the spindle, it should not be

removed until its position has been marked as shown in Fig. 69. Scribe a radial line *a* on the nose of the spindle, and a line *b* lengthwise of the center and coinciding with line *a*. The center should be replaced always in this position in the spindle.

INSTALLING AND MAINTENANCE OF LATHES

TESTING ACCURACY OF LATHE

109. Installing New Lathes.—All finished surfaces of new lathes that are sent out from the factory are covered with grease to protect them from moisture. This grease has to be removed with gasoline or benzine when the lathe

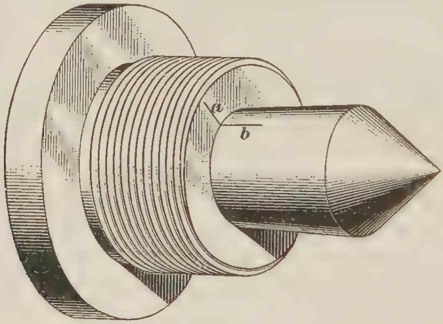


FIG. 69

is being installed. A solid stone or concrete foundation should be provided for the machine and the bed should be accurately leveled with 18-inch metal levels. The levels should be placed at different places, such as *a*, *b*, and *c*, across the **V**'s and parallel with the **V**'s, as in Fig. 70, and adjustment is made by the use of wedges *d* underneath the legs of the bed. Usually the first adjustment is made with wooden wedges driven in alternately, on opposite sides of the bed, to lift the machine without twisting the bed. Then the wooden wedges are replaced by metal wedges until the bed is perfectly level, and set at least 18 inches from any wall, and have at least $3\frac{1}{2}$ feet clearance in front.

The oil ducts and passages should all be located next and carefully cleaned with gasoline or kerosene and fresh oil should be introduced.

The lathe need not be screwed down to the floor. Where the foundation is solid it is neither necessary nor advisable to bolt the lathe down, as the tightening of the bolts or screws tend to throw the bed out of level.

110. Accuracy of New Lathes.—In the manufacture of lathes, all parts are carefully tested to see whether the center

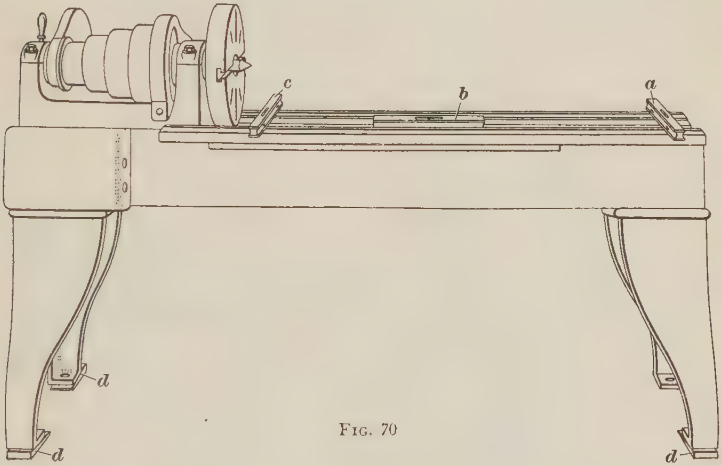


Fig. 70

line of the spindles is exactly parallel with the bed, the carriage square across the bed, and all parts correct. All these tests require that the lathe shall produce work within a limit of from .00025 to .001 inch, depending on the kind of work. The lathe beds are carefully planed and scraped by means of templets and tested with suitable gauges. One way of testing the beds for accuracy is by means of four blocks of equal thickness placed at regular intervals across the bed. A straightedge is then put on the test blocks and tissue papers placed between the blocks and the straightedge. If these papers do not pull through evenly, the beds are replaned.

111. Lining Lathe Centers.—To turn work square and parallel, it is necessary that the lathe centers be in line with each other and with the line of tool motion. If the centers are much out of line, as they would be after turning a taper, they may be roughly set by placing the dead center very close to the point of the live center and adjusting until the points appear to be opposite, or the dead center may be set by the use of the scale or zero mark on the tailstock. To adjust the dead center accurately, a test bar about 1 foot long may be used. It is carefully centered with its ends finished to the same diameter, and the middle portion slightly reduced. This bar is held between the lathe centers and the dial gauge is adjusted to touch the bar at the live-center end. After the tool is thus adjusted, the carriage is moved to the dead-center end and the tailstock is adjusted so that the gauge reads the same at this end. The test should be repeated until the centers are alike at both ends. After the centers are lined, the work being turned should be carefully calipered as the cut proceeds, to be sure that the lining was correctly done.

112. The use of a 1-foot test bar would not insure accurate alinement of the centers for work more than a foot long, or after the tailstock had been moved from where the setting was made. In such a case a test could be made by turning a short place true on the ends of the work. The tool is set so a block or gauge just passes between the tool and the turned part. The piece is turned end for end and the centers adjusted until the gauge shows the same clearance at both ends.

113. Wear of Tool.—Sometimes when the centers are correctly lined, the work may be slightly tapered, growing larger at the headstock end, owing to the wearing away of the point of the tool. A long, springy shaft will taper larger toward the middle as the tool feeds toward the headstock during a heavy cut. This taper will increase until the middle is reached, and decrease the remainder of the distance. Taper resulting from spring usually corrects itself during the finishing cut.

114. Testing Alinement of Live Spindle.—The next test is to ascertain whether the live spindle is accurately parallel with the **V**'s. This may be done with a 2-foot test bar of correct diameter and held in the live-spindle taper. Readings are taken at different points along the bar with a dial gauge held in the sliding block *a*, Fig. 71, which is mounted on the carriage. For accurate alinement the variation in readings should not be more than .001 inch.

The same bar may be used for determining the accuracy of alinement of both lathe centers. This should always be done

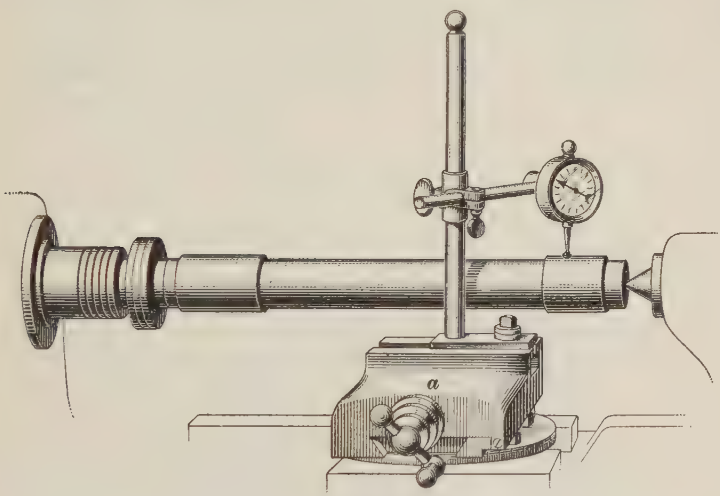


FIG. 71

in installing a new lathe. After the live spindle has been tested and proved correct, the tailstock is moved up until its center comes in contact with the end of the test bar, as in Fig. 71. If the centers are not in line the dial indicator will show as many thousandths error as the amount the tailstock center is out of line. Scraping the tailstock ways and adjusting the set-over screws in the tailstock base must be resorted to until the alinement is correct.

115. Testing Alinement of Tailstock Spindle.—The tailstock is next moved up again but with the spindle extended to

the limit of its travel, until the center enters the hole in the end of the bar. If the dial gauge shows no appreciable variation in the readings along the bar the tailstock spindle is correctly alined with the **V**'s of the lathe.

116. Testing Alinement of Cross-Slide.—A tram or squaring arbor is inserted in the headstock spindle with the arm *a*, Fig. 72, at right angles to the spindle axis, and a reading is taken with the dial gauge at the outer end of the arm while the gauge is held in a sliding block mounted on the cross-slide. The arm is then swung around 180° to the rear of the lathe, as shown at *b*, and the sliding block and the gauge are moved to the rear of the lathe, and another reading is taken. If the carriage bridge is not perfectly square with the spindle axis the gauge readings will vary

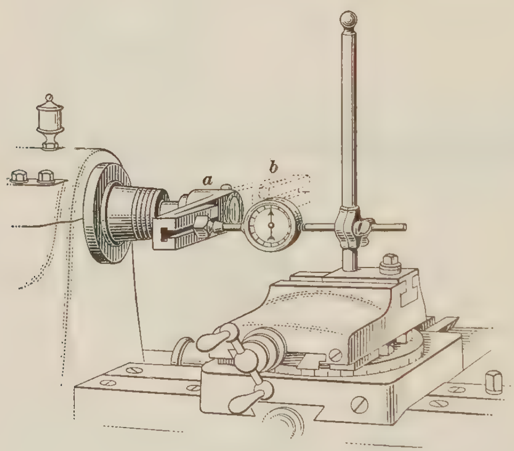


FIG. 72

and the carriage ways should be scraped until the readings show the carriage to be square.

117. Testing Lathe Face Plate.—After attaching a new face plate a light cut is taken on its face. The plate is then tested on several diameters with a straightedge *a*, Fig. 73, and tissue papers *b* are pulled through between the

plate and the straightedge, to determine whether or not the face of the plate is straight.

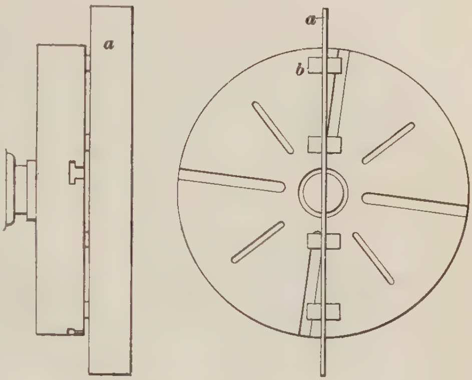


FIG. 73

118. Adjustment of Spindle Bearing. When after operating a certain time a spindle becomes too loose in its bearings, the operator should loosen the bolts that hold the bearing caps down to the base of the bearing and remove one or more thicknesses of shim from between cap and base. The shims are laminated and soldered together in layers, and may be easily separated. An equal amount of shim thickness should be removed on each side of the bearing. When the spindle cap is being clamped back in place the bolts on one side should not be pulled down tight before the opposite bolts are adjusted. It is better to adjust alternately the two bolts diagonally opposite. The remaining screws can then be tightened.

119. Adjustment of End Play in Lead Screw.—Occasionally the lead screw should be tested for end-motion, as this frequently is the cause of inaccuracies in thread cutting. The spindle is stopped, the half nuts are closed upon the lead screw and with the hand wheel on the apron an attempt is made to move the lead screw endwise. Any end motion that is found may be taken up by readjusting the collar at the end of the screw outside of the feed-box.

120. Care of Spindle Bearing.—The lower half of the cast-iron spindle bearing box is shown in Fig. 74. The sides are milled vertically, as shown at *a* so as to fit into the headstock. After this operation the top and bottom parts are clamped together with shims in between, and carefully bored

out and slotted, as shown in (*a*). The Babbitt *b* is then poured in the slots and the two parts are again clamped, and bored out to the exact diameter of the spindle. The finished lower half of the bearing is shown in (*b*). If the Babbitt becomes worn it must be renewed. First the old Babbitt is melted out, after which a dummy shaft, covered with paper or coated with graphite slightly smaller in diameter than the spindle, is put in the place of the spindle and the ends of the box are

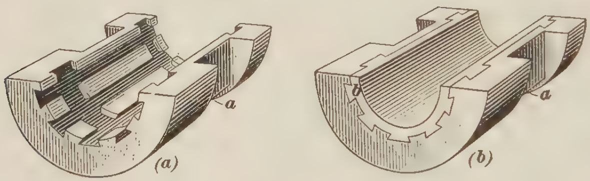


FIG. 74

closed with clay. Babbitt is then poured around the dummy shaft and the box up to the top. The Babbitt is then bored out and reamed to the exact diameter of the spindle and carefully hand-scraped to make a perfect fit.

LATHE LUBRICATION

121. Like any machine tool the lathe must be kept well-oiled to give satisfactory performance. Every oil hole should be familiar to the operator, as every hole is provided for a definite purpose. If one hole is slighted, some part of the machine will suffer as a consequence. None but high-grade oils should be used. Lard oil should not be used on internal parts, but is satisfactory on exposed surfaces.

It is a good plan to go over the lathe at least once a day to see that every revolving part has received sufficient oil. The headstock spindle, the apron mechanism, and the lead-screw bearings should receive special daily attention. On the large and small steps of the cone on the cone-driven lathe are two small headless setscrews, that have to be removed for oiling the spindle bearings. The operator should use plenty of oil on the lead screw and half nuts before cutting a thread.

122. The **V**'s of the lathe bed must be oiled thoroughly and the carriage should be run over the oiled surface before starting the cut, so that the oil is properly distributed. A few drops of oil on the spindle nose will allow the face plate to screw on much easier. Special care should be taken to oil the dead center frequently to prevent this center from heating. On gearing, such as feed-gears, motor-drive connecting gears, etc., a heavy grease should be used to reduce noise and produce smooth running under heavy duty. The boxes and pulley bearing of the countershaft should be filled with good engine oil at least once a week.

On heavy-duty lathes the headstock spindle bearings are usually ring-oiled, or they may be oiled by an oil-circulation system. The surplus oil in the latter case is drained into settling and filtering tanks, whence it is drawn by a power-driven pump.

LATHE BELTING

123. The smooth, or hair, side of the skin from which the leather belt was made, should be next to the pulley so that in passing over the pulley there shall be no air pockets, which may cause the belt to slip. A good grade of double belting must be used, both for the lathe and overhead shafting and from time to time a good belt dressing should be applied to the back of the belt to keep it pliable. Belt laces should not be crossed on the side next to the pulley, as they prevent the belt from hugging the pulley and are easily worn in two. A steel tape should be used to measure the length of a belt. The main consideration is that belts be kept tight, but not so tight as to cause trouble with the bearings. Rosin should never be used to prevent slipping, as it ruins the belt, which in a short time will slip worse than before.

LATHE CUTTING SPEEDS AND FEEDS

CUTTING SPEEDS

124. Definition of Lathe Cutting Speed.—The cutting speed of a lathe tool is the rate at which it cuts the work, measured in feet per minute. It is the surface speed of the revolving work in feet per minute, and equals the circumference of the work in feet multiplied by the revolutions per minute.

125. The surface speed of the work depends upon the diameter of the work and the number of revolutions. Suppose that two lathes are running at 100 revolutions per minute, and that one is turning a piece 1 inch in diameter while the other is turning a piece 2 inches in diameter. The circumference of the 1-inch piece is 3.14 inches, and that of the 2-inch piece is twice as great, or 6.28 inches. At 100 revolutions per minute the surface speed of the 1-inch piece is $\frac{100\times 3.14}{12} = 26$ feet 2 inches. The surface of the 2-inch piece has twice this speed, or 52 feet 4 inches. It should be noted that a length in inches must be divided by 12 in order to get the length in feet.

126. Relation of Cutting Speed to Material and Tool. The cutting speed depends upon the tool, the material cut, and the machine. Tools of high-speed steel will stand about twice the cutting speed of carbon-steel tools. For example, it is usually expected that carbon-steel lathe tools will cut low-carbon steel and soft castings at about 30 feet per minute, and the speed for high-speed steel tools is 70 feet per minute.

The harder the material the lower the cutting speed; on the other hand, soft materials are usually run at high speeds. Thus, copper, tin, zinc, brass, etc., may be run up to 180 feet per minute with carbon-steel tools when making light cuts. On soft steel very light cuts, $\frac{1}{32}$ inch or so, can be made with high-speed tools at as much as 500 feet per minute. However, engine lathes are not intended to run for any length of

time fast enough to give such high cutting speeds on small work.

127. If the machine is rigid, has plenty of power, and is in good condition, the limit of the cutting speed depends upon the durability of the tool. Therefore, the limit of cutting speed is the greatest speed at which the tool will retain its cutting edge long enough to turn out a fair amount of good work. The tool should not require grinding oftener than about once in $1\frac{1}{2}$ or 2 hours. However, with forming tools, which are more expensive than the ordinary turning tools, the regrinding should be less frequent. Therefore, with these tools the cutting speeds must be low and the cuts very light, that is, these tools should be used for finishing cuts, and at speeds from 30 feet to 50 feet on soft steel, and from 60 feet to 75 feet on brass with carbon-steel tools. These speeds may be increased with high-speed steel tools.

128. Method of Speeding the Work.—The work is started at any of the ordinary speeds stated above, and then varied from that as the operation indicates. If the tool cuts freely without showing signs of wear for 3 hours or more, it is safe to speed up the work until the limit for regrinding becomes 2 hours or less.

129. Cutting Speeds for Roughing and Finishing Cuts. Roughing cuts are generally heavy and generate much heat. It therefore becomes necessary to use slower cutting speeds for roughing than for finishing cuts, to prevent burning the tool.

Finishing cuts when short, are best made at a high cutting speed, especially on cast iron, as a smoother surface will result than can be obtained with a slower cut. When a slow cutting speed is used on cast iron, there is a tendency for the shavings to break out of the work slightly in advance of the cutting edge, because of the crystalline structure of the material. When the slow speed is used, the shaving breaks slowly from the work and in so doing breaks into the surface and carries away with it particles of metal that should be left. This leaves a surface that is more or less pitted, and should it be

desired to finish it by polishing, these little pits will be found of sufficient depth to make it very difficult to obtain a fine polish. When a higher speed is used, or the tool is ground with a keener cutting edge, this pitting will disappear.

130. Average Cutting Speeds for Carbon-Steel Tools.—In Table I are given fair speeds that may be used for taking roughing cuts of medium depth with carbon-steel tools.

TABLE I

RELATIVE CUTTING SPEEDS OF METALS WITH CARBON-STEEL TOOLS

Material	Diameter of Work Inches	Cutting Speed in Feet Per Minute
Wrought Iron and Machine Steel	$\frac{1}{2}$	38
	1	35
	$1\frac{1}{2}$	30
	2	28
	$2\frac{1}{2}$	25
Cast Iron	1	45
	$1\frac{1}{2}$	45
	2	40
	$2\frac{1}{2}$	40
Tool Steel	$\frac{3}{4}$	24
	$\frac{7}{8}$	20
	1	20
	$1\frac{1}{2}$	18
Brass	$\frac{3}{4}$	110
	1	100
	$1\frac{1}{4}$	90
	$1\frac{1}{2}$	80

It will be noticed in this table that the cutting speed of brass is considerably greater than that of iron or steel, and that the cutting speed is increased for the small diameters of work, although, theoretically, the diameter of the work should not affect the cutting speed. The cutting speeds given for cast iron are for short cuts taken on very soft castings. Long, continuous cuts on hard castings require a speed somewhat

below that given in the table. Experience has shown that a higher cutting speed can be used on machine steel than on cast iron that is gritty, because of the dulling effect of the grit on the tool.

131. Use of Low Cutting Speeds.—When the accuracy of the piece depends on the action of the cutting tool, then that tool should be favored by using lower cutting speeds. For example, consider a reamer that is to finish holes smooth and true and to an exact diameter within a thousandth of an inch. The size of the hole will depend on the size of the reamer, and when the cutting edge is worn away one-half thousandth of an inch, the reamer will make the holes too small. Such a tool should be handled with care and the cutting speed sacrificed for the sake of maintaining the cutting edge. Taps and dies should not be run at such high cutting speeds as can be used for lathe tools. Chucking tools should also be favored, especially if they are intended to remain at a particular size.

132. Finding Cutting Speed.—According to the definition, the cutting speed of a turning tool may be found by multiplying the circumference of the work, in feet, by the number of revolutions per minute. The circumference of a circle, in feet, is found by multiplying the diameter, in inches, by 3.1416 and dividing the product by 12; thus, a piece 3 inches in diameter has a circumference of $3 \times 3.1416 = 9.4248$ inches, or $9.4248 \div 12 = .7854$ foot. As $3.1416 \div 12 = .2618$, the calculation may be shortened by multiplying the diameter, in inches, by .2618 to find the circumference in feet; that is, for a piece 3 inches in diameter, the circumference is $3 \times .2618 = .7854$ foot. The cutting speed in any case may be found by the following rule:

Rule.—*To find the cutting speed, in feet per minute, multiply .2618 times the diameter of the work, in inches, by the number of revolutions per minute of the work.*

Example.—A shaft that is being turned to a diameter of $2\frac{1}{2}$ inches makes 75 revolutions per minute. What is the cutting speed?

Solution.—Applying the rule, the cutting speed is

$$.2618 \times 2\tfrac{1}{2} \times 75 = 49 \text{ ft. per min.} \quad \text{Ans.}$$

133. Finding Revolutions for Desired Cutting Speed. When a certain cutting speed has been decided for a given piece of work, it may be necessary to find the number of revolutions per minute that the work must make, which may be done by the following rule:

Rule.—*To find the number of revolutions per minute corresponding to a desired cutting speed, divide the cutting speed by .2618 times the diameter of the work, in inches.*

EXAMPLE.—How many revolutions per minute must a 9-inch steel shaft make to give a cutting speed of 20 feet per minute?

SOLUTION.—Applying the rule, the required speed is

$$\frac{20}{.2618\times 9}=8\tfrac{1}{2}\text{ R. P. M.}\quad\text{Ans.}$$

134. Finding Time Required to Take Cut.—The time required to take a cut over a piece of work of known diameter, with a given feed and a fixed cutting speed may be calculated by the following rule:

Rule.—*To find the time, in minutes, required to turn a piece of work, multiply .2618 times the diameter of the work, in inches, by the length of the work, in inches, and divide this product by the cutting speed in feet per minute multiplied by the feed in inches per revolution of the work.*

EXAMPLE.—How long will it take to turn up a flywheel 20 feet in diameter and with a 24-inch face if the cutting speed is 15 feet per minute and the feed is $\frac{1}{2}$ inch per revolution of the wheel?

SOLUTION.—A diameter of 20 ft. is equal to 240 in. Applying the rule, the time required is

$$\frac{.2618\times 240\times 24}{15\times\frac{1}{2}}=201\text{ min.}=3\text{ hr. }21\text{ min.}\quad\text{Ans.}$$

FEED

135. Definition.—There are two ways of expressing the feed of a tool. Usually, feed is taken to mean the amount of sidewise movement of the tool along or across the bed during one complete revolution of the work; thus, if a tool moves $\frac{1}{8}$ inch lengthwise of the bed while the work makes one turn, the feed

is $\frac{1}{8}$ inch. Sometimes the feed is expressed as the number of revolutions made by the work while the tool moves 1 inch along the bed; thus, a feed of 10 indicates that the work makes 10 turns while the tool moves 1 inch, which corresponds to a movement of $\frac{1}{10}$ inch for each revolution.

136. Relation of Feed to Material and Shape of Cutting Tool.—The best feed to use on a piece of work depends on many conditions. When cylindrical accuracy is desired on wrought-iron or steel shafts, it is best to use a fine feed for finishing, since, with a fine feed, it is possible to use a tool with a narrow point. The narrow-pointed tool will cut more freely and consequently with less spring to the tool and the work. Time, however, is of great importance in machine work, and sometimes coarser feeds will finish with sufficient accuracy.

137. If the tool is ground with a wide enough point the surface is left smooth and not with a series of ridges. This depends very much on the rigidity with which the tool and the work are held in relation to each other. In the manufacture of turned steel shafting, a very acceptable finish is obtained with a feed as high as five to the inch, but the work runs in an ample follow rest and is supported at frequent intervals along its length.

If the work is to be finished by grinding, there is a distinct advantage in using a round-nosed tool and leaving the surface with ridges. Then the grinding wheel takes off the point of the ridge at its first traverse and only comes to the full cut gradually instead of taking it all in one traverse.

138. Relative Action of Feed on Cast Iron and Steel. Cast iron will generally admit of heavier feeds than wrought iron or steel. This is due largely to the difference in the action of the shaving on the tool. In cast iron there is a tendency for the shaving to break immediately when it is turned out of its course by the top face of the cutting tool. This constant breaking of the shaving tends to relieve the tool of undue pressure. In wrought iron or steel the shaving does not break up so easily.

When, in turning steel, the broad cutting edge of the tool is set parallel to the axis of the work, any slight pressure that may tend to spring the tool into the work causes the whole broad edge to spring in. The tool will take instantly a very much deeper hold, and, because of the tenacity of the steel, the tool will be carried deeper and deeper until it reaches a point where the strain on the tool balances the pressure of the shaving, at which point the tool will continue to cut at this depth. If the work is not sufficiently rigid to hold its shape while the tool is thus sprung and taking a deep cut, the piece will bend slightly. As the hollow side of the bent piece comes around to the tool, the cut will grow less until the heavy side again comes around, whereupon the cut will be heavier than before, and in most cases the work will be ruined. Broad cutting-edged tools should never be put on a piece of wrought iron or steel, unless the operator is quite sure that there is sufficient rigidity to withstand the cut.

139. Advantage of Coarse Feed.—When the finishing cut is being taken on a large piece, it is desirable to have the tool retain its sharp edge until the operation is completed, so that the last part of the cut will be as smooth and true as the first. On heavy work it is best to use a coarse feed and slow cutting speed.

Suppose that it is desired to turn up a heavy flywheel 20 feet in diameter, having a 24-inch face. The cutting speed is 18 feet per minute and a feed of $\frac{1}{10}$ inch is used. The time required would then be

$$\frac{.2618 \times 240 \times 24}{18 \times \frac{1}{10}} = 838 \text{ minutes}$$

This is equal to 13 hours 58 minutes. Also, the length of shaving with $\frac{1}{10}$-inch feed would be $3.1416 \times 20 \times 24 \div \frac{1}{10} = 15{,}080$ feet, or nearly 3 miles. No tool would cut nearly 3 miles of shaving without getting dull, and the time would be considerably more than is necessary. On such a piece, the feed would be increased to nearly 1 inch per revolution and the cutting speed reduced to about 15 feet per minue. This

would reduce the length of the shaving to 1,508 feet, and would require about 100 minutes, or 1 hour 40 minutes. The time is thus decreased to about one-tenth the original, which makes it possible to use a tool that will last throughout the cut.

LATHE THREAD CUTTING

ENGINE LATHE OPERATIONS

KINDS OF SCREW THREADS

DEFINITIONS

1. Terms Applied to Screw Threads.—The common form of screw thread shown in Fig. 1 is made by cutting a continuous **V**-shaped groove around a cylinder. The outer edge, or surface, *a*, is called the *point*. The inner edge, or surface, *b* is called the *root*. The vertical distance *h* from the root to the point is called the *height*, or *depth*. The distance *p* between two points, measured parallel to the axis of the thread, is called the *pitch*. The pitch is equal to 1 divided by the number of threads in 1 inch measured parallel to the axis.

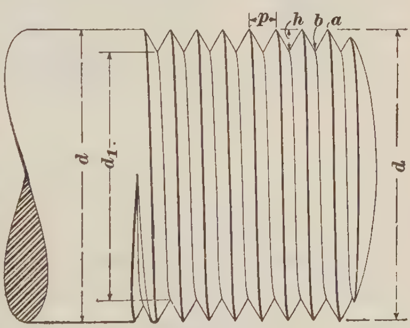


FIG. 1

Thus, a thread having 6 points per inch, has a pitch that measures $1 \div 6 = \frac{1}{6}$ inch. The term pitch is also applied as a number as well as a measured distance as defined above. For example, a thread having 6 points per inch is called a 6-pitch thread.

The distance d measured over the points a is the *outside diameter* of the thread. The distance d_1 measured through the screw from root to root is the *root diameter.*

2. Single and Multiple Threads.—A *single thread* is one formed by a single continuous groove spaced the width of the thread apart, as in Fig. 1. A *double thread* is formed by two separate grooves, as 1 and 2 in Fig. 2, the spacing of the grooves being twice the width of a single thread. The unfinished part of thread 2 shows the double spacing of the

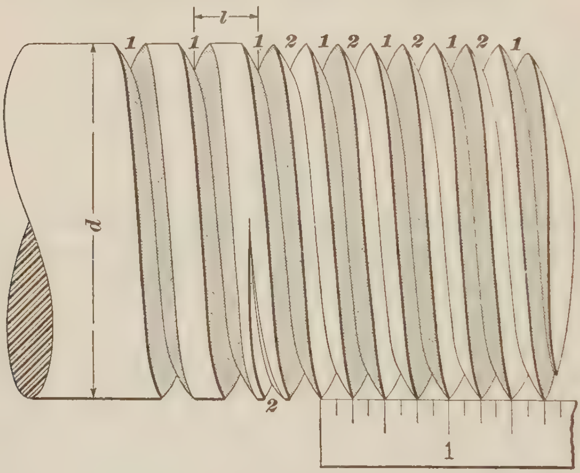


FIG. 2

groove for thread 1. A triple thread has three separate threads and a quadruple thread consists of four separate threads. Double, triple, quadruple, etc., threads are also called *multiple threads.* Each thread in Fig. 2 is similar to the thread in Fig. 1, but in Fig. 2 the threads advance twice as far in one turn as in Fig. 1.

3. Lead of Thread.—The distance a thread advances in one turn is called its *lead.* With a single thread the lead is the same as the pitch p, Fig. 1. With a double thread the lead l, Fig. 2, is twice the pitch. Likewise, with a triple

thread the lead is three times the pitch, and with a quadruple thread it is four times, and so on.

4. External and Internal Threads.—A thread cut on the outside of the work is called an *external thread*, and when cut on the inside of the work, as in a nut or collar, it is called an *internal thread*.

5. Right- and Left-Hand Threads.—When a threaded piece, being screwed into a nut, must be turned in the direction of the hands of a watch, the thread is a *right-hand thread;* but if it must be turned in the opposite direction, the thread is a *left-hand thread*. Unless otherwise stated, threads are understood to be right-hand.

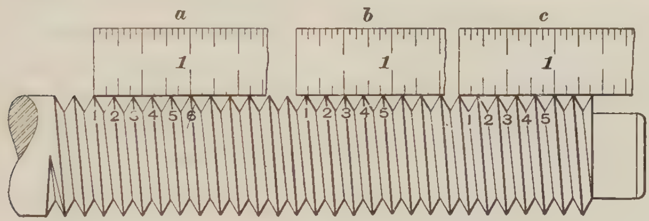


FIG. 3

6. Measuring Pitch of Threads With a Scale.—Three methods of measuring the number of turns of a thread in 1 inch are shown in Fig. 3.

At *a* is shown a scale set on the screw so that its end is in line with one thread point. Another thread point is opposite the first inch mark. Counting from the end up to and including the first inch mark, there are six thread points, as numbered; but the sixth point is really the first point in the next inch; so it is dropped. There are 5 points per inch, therefore, and so the screw is said to have 5 threads per inch, or a pitch of $\frac{1}{5}$ inch.

7. Another method of finding the number of threads per inch is shown at *b*, Fig. 3. The end of the scale is set in line with the root of a thread space, and the number of points between this space and the first inch mark is counted. In

this case, there are 5 points; consequently, the screw has 5 threads per inch. Still another method is to place the scale as at *c*, with one end in line with a thread point, and to count the number of spaces between the end and the first inch mark. In this case there are five spaces, showing that the screw has 5 threads per inch.

8. The three methods that have just been described give correct results *only* when there is a whole number of threads per inch; that is, the end of the scale and the first inch mark must both coincide with thread points. If the end of the scale is in line with a thread point and the first inch mark comes opposite a space, the screw has a fractional number of threads. In such a case the counting must be continued until a point is reached where a thread point coincides with a full-inch mark; then the total number of points counted, less one, divided by the number of inches, will give the number of threads per inch. For example, in measuring a certain screw the end of the scale is even with a thread point, and 24 points are counted before a thread point again comes opposite a full-inch mark, which is the 2-inch mark. Dropping the last point counted, there are 23 points in 2 inches, or $23 \div 2 = 11\frac{1}{2}$ points per inch; therefore, the screw has $11\frac{1}{2}$ threads per inch.

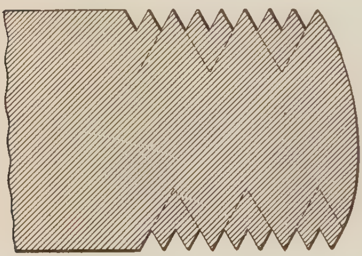


Fig. 4

9. Measuring Lead of Multiple Threads.—In measuring a multiple-threaded screw, the lead is usually desired. In the case of a double-threaded screw, like that in Fig. 2, only every other point would be counted. In this case, there are two points to the inch; then the lead is $\frac{1}{2}$ inch. The actual number of threads per inch is 4, and the pitch is $\frac{1}{4}$ inch. Multiple threads are used when a long lead is desired on a screw of small diameter. By cutting a number of threads in place of one large thread, it is possible to keep the long lead

without cutting very deeply into the piece. In Fig. 4 is shown a section of a screw with triple threads. The dotted lines show the depth to which it would be necessary to cut a single thread of the same lead.

10. Measuring Thread Pitch on a Short Screw.—If the threaded part is very short, such as a nut and a screw-pitch gauge is not available, the approximate measure of the pitch may be made as follows: Press a piece of soft wood against the thread so as to make an impression of the thread points on the wood. Then measure the impressions as previously explained. A bit of soft wood, such as a lead-pencil, may be introduced into a nut and an impression of the points made on the wood. As the pitch of most threads can be expressed in simple fractions, a very close estimate can be made by this method. A metric rule should be used where it is suspected that the pitch is metric.

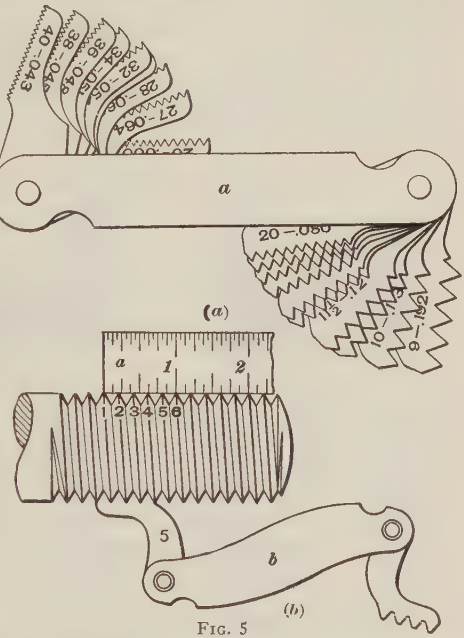


Fig. 5

11. Screw-Pitch Gauge.—The number of threads per inch may be measured by a screw-pitch gauge. It consists of a number of thin steel leaves pinned at each end of a handle such as that shown at *a*, Fig. 5 (*a*). Each leaf is cut on its edge with the correct pitch of the thread designated by the number stamped on it. The set of narrow leaves on the left is intended for inside threads, as these leaves can be introduced into a small hole. The decimals stamped on the leaves indicate the double depth of the threads,

which is a dimension needed when selecting the size of drill for making the hole in a nut. The gauge shown in Fig. 5 is for a 60-degree sharp **V** thread. To measure a thread, as shown in (*b*), simply apply one or more leaves to it until one is found that exactly fits the thread.

SHAPE OF SCREW THREADS

12. Sharp, or V, Thread.—The shape of a sharp, or **V** thread is shown in Fig. 6. The sides of the thread are straight and make an angle of 60 degrees with each other, and 60 degrees with the center line of the screw. These side faces meet and form a sharp point *a* and a sharp corner *b* at the root; hence its name, sharp, or **V**, thread. The pitch is here denoted by *p*,

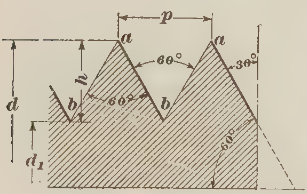


FIG. 6

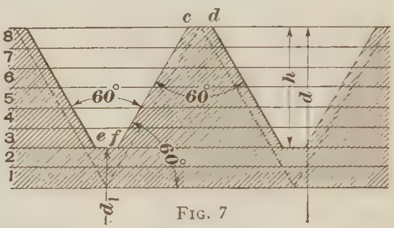


FIG. 7

the depth of the thread by *h*, the diameter of the bolt by *d*, and the diameter at the root of the thread by d_1. Table I gives the principal dimensions of **V** threads.

The depth *h* of a **V** thread may be found by multiplying its pitch *p* in inches by .866, or $h = .866 \times p$.

EXAMPLE.—Required the depth of a **V** thread having a pitch of $\frac{1}{2}$ inch.

SOLUTION.— $.866 \times \frac{1}{2} = .433$ inch. Ans.

13. United States Standard Thread.—The shape of the United States Standard thread is shown by the full lines in Fig. 7. In order to compare it with the sharp **V** thread, a **V** thread of equal pitch is drawn in dotted lines. The sides of the United States Standard thread make an angle of 60 degrees with each other and with the center line of the screw, just as in the **V** thread; but the point and root of the United States Standard thread are flat. The widths *c d* and *e f* of the flat

TABLE I

DIMENSIONS OF SHARP, OR V THREADS

Diameter of Bolt Inches d	Number of Threads per Inch	Diameter at Root of Thread Inches d_1	Depth of Thread Inch h	Pitch Inch p
$\frac{1}{4}$	20	.1634	.0433	.0500
$\frac{5}{16}$	18	.2163	.0481	.0556
$\frac{3}{8}$	16	.2668	.0541	.0625
$\frac{7}{16}$	14	.3138	.0618	.0714
$\frac{1}{2}$	12	.3557	.0722	.0833
$\frac{9}{16}$	12	.4182	.0722	.0833
$\frac{5}{8}$	11	.4676	.0787	.0909
$\frac{3}{4}$	10	.5768	.0866	.1000
$\frac{7}{8}$	9	.6826	.0962	.1111
1	8	.7835	.1083	.1250
$1\frac{1}{8}$	7	.8776	.1237	.1429
$1\frac{1}{4}$	7	1.0026	.1237	.1429
$1\frac{3}{8}$	6	1.0863	.1443	.1667
$1\frac{1}{2}$	6	1.2113	.1443	.1667
$1\frac{5}{8}$	5	1.2786	.1733	.2000
$1\frac{3}{4}$	5	1.4036	.1733	.2000
$1\frac{7}{8}$	$4\frac{1}{2}$	1.4901	.1924	.2222
2	$4\frac{1}{2}$	1.6151	.1924	.2222
$2\frac{1}{8}$	$4\frac{1}{2}$	1.7402	.1924	.2222
$2\frac{1}{4}$	$4\frac{1}{2}$	1.8652	.1924	.2222
$2\frac{3}{8}$	$4\frac{1}{2}$	1.9902	.1924	.2222
$2\frac{1}{2}$	4	2.0670	.2165	.2500
$2\frac{5}{8}$	4	2.1920	.2165	.2500
$2\frac{3}{4}$	4	2.3170	.2165	.2500
$2\frac{7}{8}$	4	2.4420	.2165	.2500
3	$3\frac{1}{2}$	2.5052	.2474	.2857
$3\frac{1}{8}$	$3\frac{1}{2}$	2.6301	.2474	.2857
$3\frac{1}{4}$	$3\frac{1}{2}$	2.7551	.2474	.2857
$3\frac{3}{8}$	$3\frac{1}{4}$	2.8412	.2666	.3077
$3\frac{1}{2}$	$3\frac{1}{4}$	2.9668	.2666	.3077
$3\frac{5}{8}$	$3\frac{1}{4}$	3.0918	.2666	.3077
$3\frac{3}{4}$	3	3.1727	.2886	.3333
$3\frac{7}{8}$	3	3.2977	.2886	.3333
4	3	3.4227	.2886	.3333

are $\frac{1}{8}$ of the pitch. The illustration shows the depth of a **V** thread divided into eight equal parts. The United States Standard thread of the same pitch is three-fourths the height of the **V** thread, as shown. A screw having United States Standard threads is stronger than a screw of equal size with **V** threads, because the diameter at the root of the United States Standard thread is greater than the diameter at the root of the **V** thread.

The depth of the United States Standard thread may be found by multiplying its pitch p, in inches, by .6495, or $h = .6495 \times p$.

EXAMPLE.—Required the depth of a United States Standard thread having a pitch of $\frac{1}{3}$ inch.

SOLUTION.—The depth is $.6495 \times \frac{1}{3} = .2165$ inch. Ans.

14. Adoption of United States Standard Thread.—The United States Standard thread was authorized for use in the naval service by the government in the year 1868. In the year 1871, the Master Car Builders' Association recommended it for use in the construction of locomotives and cars. The system is now entirely used in the United States Navy, and has been adopted by manufacturers generally. It is used on commercial capscrews. It has not entirely taken the place of the **V**-thread system, however, as for very small screws and fine pitches the **V** thread is more often used. Table II gives the number of threads per inch to be cut on each size of a bolt to meet the requirements of the standard.

15. A. S. M. E. Standard Thread.—In order that machine screws might be made interchangeable the American Society of Mechanical Engineers has established a standard form of thread, known as the A. S. M. E. Standard. (See Table III.) The thread is of the same form as the United States Standard thread and the proportions for the depth of thread and for the width of flat have been derived by applying the same formula as in the case of the United States Standard thread.

16. Square Thread.—The square thread, as its name implies, is square in section, as shown in Fig. 8. Theoretically,

TABLE II

DIMENSIONS OF UNITED STATES STANDARD THREADS

Diameter Inches d	Number of Threads per Inch	Diameter at Root of Thread Inches d_1	Depth of Thread Inch h	Width of Flat Inch ef or cd	Pitch Inch p	Depth Ground from V-Point Tool Inch
$\frac{1}{4}$	20	.185	.0325	.0062	.0500	.0270
$\frac{5}{16}$	18	.240	.0361	.0069	.0556	.0338
$\frac{3}{8}$	16	.294	.0406	.0078	.0625	.0406
$\frac{7}{16}$	14	.345	.0464	.0089	.0714	.0471
$\frac{1}{2}$	13	.400	.0500	.0096	.0769	.0541
$\frac{9}{16}$	12	.454	.0541	.0104	.0833	.0608
$\frac{5}{8}$	11	.507	.0590	.0114	.0909	.0676
$\frac{3}{4}$	10	.620	.0650	.0125	.1000	.0812
$\frac{7}{8}$	9	.731	.0722	.0139	.1111	.0947
1	8	.838	.0812	.0156	.1250	.1082
$1\frac{1}{8}$	7	.939	.0928	.0179	.1429	.1217
$1\frac{1}{4}$	7	1.064	.0928	.0179	.1429	.1352
$1\frac{3}{8}$	6	1.158	.1082	.0208	.1667	.1487
$1\frac{1}{2}$	6	1.283	.1082	.0208	.1667	.1623
$1\frac{5}{8}$	$5\frac{1}{2}$	1.389	.1181	.0227	.1818	.1758
$1\frac{3}{4}$	5	1.490	.1299	.0250	.2000	.1894
$1\frac{7}{8}$	5	1.615	.1299	.0250	.2000	.2029
2	$4\frac{1}{2}$	1.711	.1444	.0278	.2222	.2164
$2\frac{1}{4}$	$4\frac{1}{2}$	1.961	.1444	.0278	.2222	.2434
$2\frac{1}{2}$	4	2.175	.1624	.0313	.2500	.2705
$2\frac{3}{4}$	4	2.425	.1624	.0313	.2500	.2976
3	$3\frac{1}{2}$	2.629	.1856	.0357	.2857	.3246
$3\frac{1}{4}$	$3\frac{1}{2}$	2.879	.1856	.0357	.2857	.3516
$3\frac{1}{2}$	$3\frac{1}{4}$	3.100	.1998	.0385	.3077	.3787
$3\frac{3}{4}$	3	3.317	.2165	.0417	.3333	.4058
4	3	3.567	.2165	.0417	.3333	.4328
$4\frac{1}{4}$	$2\frac{7}{8}$	3.798	.2259	.0435	.3478	.4559
$4\frac{1}{2}$	$2\frac{3}{4}$	4.027	.2362	.0455	.3636	.4869
$4\frac{3}{4}$	$2\frac{5}{8}$	4.255	.2474	.0476	.3810	.5139
5	$2\frac{1}{2}$	4.480	.2598	.0500	.4000	.5410
$5\frac{1}{4}$	$2\frac{1}{2}$	4.730	.2598	.0500	.4000	.5680
$5\frac{1}{2}$	$2\frac{3}{8}$	4.953	.2735	.0526	.4210	.5950
$5\frac{3}{4}$	$2\frac{3}{8}$	5.203	.2735	.0526	.4210	.6221
6	$2\frac{1}{4}$	5.423	.2882	.0556	.4444	.6492

TABLE III

DIMENSIONS OF A. S. M. E., OR MACHINE SCREW, THREADS

Outside Diameter of Thread Inch	Threads per Inch	Pitch Inch	Width of Flat Inch	Depth of Thread Inch	Root Diameter Inch
.060	80	.0125	.0016	.0081	.0438
.073	72	.0139	.0017	.0090	.0550
.073	64	.0156	.0019	.0101	.0527
.086	64	.0156	.0019	.0101	.0657
.086	56	.0179	.0022	.0116	.0628
.099	56	.0179	.0022	.0116	.0758
.099	48	.0208	.0026	.0135	.0719
.112	48	.0208	.0026	.0135	.0849
.112	40	.0250	.0031	.0162	.0795
.112	36	.0278	.0035	.0180	.0759
.125	44	.0227	.0028	.0148	.0955
.125	40	.0250	.0031	.0162	.0925
.125	36	.0278	.0035	.0180	.0889
.138	40	.0250	.0031	.0162	.1055
.138	36	.0278	.0035	.0180	.1019
.138	32	.0313	.0039	.0203	.0974
.151	36	.0278	.0035	.0180	.1149
.151	32	.0313	.0039	.0203	.1104
.151	30	.0333	.0042	.0217	.1077
.164	36	.0278	.0035	.0180	.1279
.164	32	.0313	.0039	.0203	.1234
.164	30	.0333	.0042	.0217	.1207
.177	32	.0313	.0039	.0203	.1364
.177	30	.0333	.0042	.0217	.1377
.177	24	.0417	.0052	.0271	.1229
.190	32	.0313	.0039	.0203	.1494
.190	30	.0333	.0042	.0217	.1467
.190	24	.0417	.0052	.0271	.1359
.216	28	.0357	.0045	.0232	.1696
.216	24	.0417	.0052	.0271	.1619
.242	24	.0417	.0052	.0271	.1879
.242	20	.0500	.0063	.0325	.1770
.268	22	.0455	.0057	.0295	.2090
.268	20	.0500	.0063	.0325	.2030
.294	20	.0500	.0063	.0325	.2290
.294	18	.0556	.0069	.0361	.2218
.320	20	.0500	.0063	.0325	.2550
.320	18	.0556	.0069	.0361	.2478
.346	18	.0556	.0069	.0361	.2738
.346	16	.0625	.0078	.0406	.2648
.372	18	.0556	.0069	.0361	.2998
.372	16	.0625	.0078	.0406	.2908
.398	16	.0625	.0078	.0406	.3168
.398	14	.0714	.0089	.0464	.3052
.424	16	.0625	.0078	.0406	.3428
.424	14	.0714	.0089	.0464	.3312
.450	16	.0625	.0078	.0406	.3688
.450	14	.0714	.0089	.0464	.3572

the space a, the width b, and the depth c should all be equal to one-half the pitch. In practice, however, the space a is made slightly greater than the width b of the thread, or as it is termed the *land*. It is customary to make the space one or one and one-half thousandths greater than the land, so that the threads will work freely and permit good lubrication. The square thread is used where a very strong thread is required and where a machine part has to be moved rapidly. It has practically flat bearing surfaces at right angles to its axis, thus avoiding the sidewise or bursting tendency found in the V-thread screw. Another advantage of the square thread is that it does not decrease in diameter, as it wears on the sides.

The pitch of the square thread is usually taken as *double* that of the United States Standard thread for the same diameter of bolt; for example, the pitch of a square thread on a 1-inch bolt is $2 \times .1250 = .25$ inch.

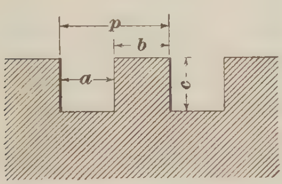


FIG. 8

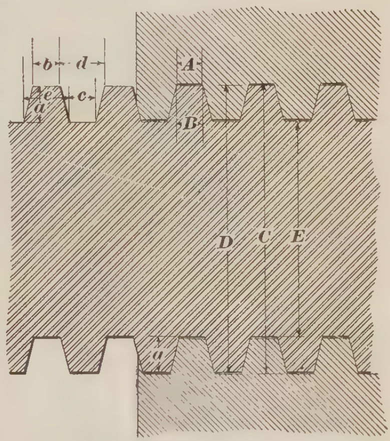


FIG. 9

Hence, the pitch p, when compared with the pitch of the United States Standard thread, may be found from the formula:

$$p = \frac{2}{\text{Number of threads per inch}}$$

EXAMPLE.—Find the pitch of a square thread on a $2\frac{1}{2}$-inch bolt.

SOLUTION.—From Table II, the number of threads per inch on a $2\frac{1}{2}$-inch bolt equals 4. The pitch $p = \frac{2}{4} = \frac{1}{2}$ in. Ans.

17. Acme Thread.—The sides of the Acme thread, shown in section in Fig. 9, are inclined $14\frac{1}{2}$ degrees, the included angle being 29 degrees. The depth of the thread is the same

as for a square thread of the same pitch. The top of the thread does not touch the bottom of the space in the nut. This opening represents the clearance, which is provided to insure a perfect fit on the sides of the thread. The Acme thread is better suited than the square thread for a feed-screw on which a split nut is used, as on the lead screw of a lathe, because the halves of the nut cannot be opened or closed on a square thread. Another advantage of the Acme thread is that it is easier to tap holes for it than for square threads, as the teeth of Acme taps are less likely to break.

TABLE IV

ACME STANDARD SCREW THREAD

Number of Threads per Inch	Depth of Thread Inch *a*	Thickness at Top of Thread Inch *b*	Width of Space at Bottom of Thread Inch *c*	Width of Space at Top of Thread Inch *d*	Thickness at Root of Thread Inch *e*
1	.5100	.3707	.3655	.6293	.6345
$1\frac{1}{3}$	.3850	.2780	.2728	.4720	.4772
$1\frac{1}{2}$	.3433	.2471	.2419	.4195	.4247
2	.2600	.1853	.1801	.3147	.3199
3	.1767	.1235	.1183	.2098	.2150
4	.1350	.0927	.0875	.1573	.1625
5	.1100	.0741	.0689	.1259	.1311
6	.0933	.0618	.0566	.1049	.1101
7	.0814	.0529	.0478	.0899	.0951
8	.0725	.0463	.0411	.0787	.0839
9	.0655	.0413	.0361	.0699	.0751
10	.0600	.0371	.0319	.0629	.0681

In Table IV the letters at the tops of the columns refer to the corresponding dimensions shown in Fig. 9. Also note that the width A of the space at the bottom of the thread in the nut is .0052 inch less than the width B of the point of the thread on the screw. The point of the Acme thread tool therefore must have a width equal to A. The dimension C is the diameter of the tap required, which is .02 inch larger than D, the outside diameter of the screw. The root diameter E is equal to the diameter D minus twice the depth a of the thread.

18. Worm Thread.—The standard worm thread, shown in Fig. 10, is similar to the Acme thread, having sides with an inclination toward each other of 29 degrees, or $14\frac{1}{2}$ degrees with the center line. The depth of the worm thread, however, is greater than the depth of the Acme thread so as to increase the wearing surface. The widths of the flats at the top and bottom of the worm thread are less. The worms of worm gearing have this form of thread. A worm may be single-threaded, double-threaded, triple-threaded, quadruple-threaded, etc., the lead of its thread being 1, 2, 3, 4, etc., times the pitch respectively. The dimensions of standard single-worm threads are given in Table V. The reference

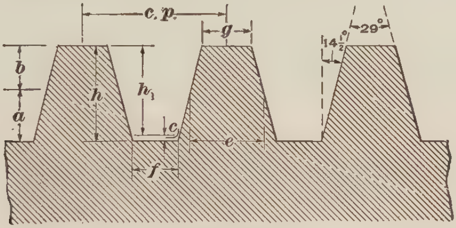


FIG. 10

letters in Fig. 10 are the same as those used in the table. For multiple threads, divide the sizes given in the table for the same pitch, by 2 for double, 3 for triple, 4 for quadruple threads, etc.

19. British Standard, or Whitworth, Thread.—In the year 1861, Sir Joseph Whitworth, of England, proposed a system of standard for screw threads to overcome the inconveniences arising in England from the use of a great number of individual systems. The system that he introduced is now the standard thread used by British manufacturers, and the same form has been adopted very largely throughout Europe. The rounding of the top and bottom of the thread has certain very desirable features, as it adds greatly to the strength and durability of the screw and does away with the sharp corners, which are liable to be nicked or bruised.

TABLE V
STANDARD SINGLE-WORM THREAD

Circular Pitch	Threads per Inch	Diametral Pitch	Depth of Tooth Above Pitch Line b	Working Depth of Tooth h^1	Clearance c	Depth of Tooth Below Pitch Line a	Whole Depth of Tooth for Worm and Hob h	Thickness of Tooth on Pitch Line e	Width of Thread Tool at End for Worm f	Width of Thread Tool at End for Hob g
2	$\frac{1}{2}$	1.5708	.6366	1.2732	.0795	.7161	1.3527	1.0000	.6296	.6708
$1\frac{3}{4}$	$\frac{4}{7}$	1.7952	.5570	1.1141	.0696	.6266	1.1837	.8750	.5509	.5869
$1\frac{1}{2}$	$\frac{2}{3}$	2.0944	.4775	.9549	.0596	.5371	1.0145	.7500	.4722	.5031
$1\frac{1}{4}$	$\frac{4}{5}$	2.5133	.3979	.7958	.0497	.4476	.8455	.6250	.3935	.4192
1	1	3.1416	.3183	.6366	.0397	.3580	.6763	.5000	.3148	.3354
$\frac{3}{4}$	$1\frac{1}{3}$	4.1888	.2387	.4775	.0298	.2685	.5073	.3750	.2361	.2515
$\frac{2}{3}$	$1\frac{1}{2}$	4.7124	.2122	.4244	.0265	.2387	.4509	.3333	.2098	.2236
$\frac{1}{2}$	2	6.2832	.1592	.3183	.0199	.1791	.3382	.2500	.1574	.1677
$\frac{2}{5}$	$2\frac{1}{2}$	7.8540	.1273	.2546	.0159	.1432	.2705	.2000	.1259	.1341
$\frac{1}{3}$	3	9.4248	.1061	.2122	.0132	.1193	.2254	.1666	.1049	.1118
$\frac{2}{7}$	$3\frac{1}{2}$	10.9956	.0909	.1819	.0113	.1022	.1932	.1429	.0899	.0958
$\frac{1}{4}$	4	12.5664	.0796	.1591	.0099	.0895	.1690	.1250	.0787	.0838
$\frac{2}{9}$	$4\frac{1}{2}$	14.1372	.0707	.1415	.0088	.0795	.1503	.1111	.0699	.0745
$\frac{1}{5}$	5	15.7080	.0637	.1273	.0079	.0716	.1352	.1000	.0629	.0670
$\frac{1}{6}$	6	18.8496	.0531	.1061	.0066	.0597	.1127	.0833	.0524	.0559
$\frac{1}{7}$	7	21.9911	.0455	.0910	.0056	.0511	.0966	.0714	.0449	.0479
$\frac{1}{8}$	8	25.1327	.0398	.0796	.0049	.0447	.0845	.0625	.0393	.0419
$\frac{1}{9}$	9	28.2743	.0354	.0707	.0044	.0398	.0752	.0555	.0349	.0372
$\frac{1}{10}$	10	31.4159	.0318	.0637	.0039	.0357	.0676	.0500	.0314	.0335
$\frac{1}{12}$	12	37.6992	.0265	.0530	.0033	.0298	.0563	.0416	.0262	.0279
$\frac{1}{14}$	14	43.9824	.0227	.0454	.0028	.0255	.0482	.0357	.0224	.0239
$\frac{1}{16}$	16	50.2655	.0199	.0398	.0024	.0223	.0422	.0312	.0196	.0209
$\frac{1}{18}$	18	56.5488	.0176	.0352	.0022	.0198	.0374	.0277	.0174	.0186

American manufacturers who are accustomed to the United States Standard thread consider the difficulty of keeping up to standard necessary tools for producing these curved points and roots a sufficient argument against the adoption of the British Standard screw thread in this country.

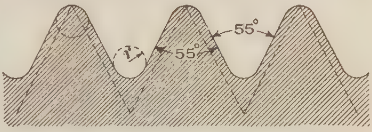


FIG. 11

20. The exact shape of the British Standard thread is shown in Fig. 11 by the full lines, and a **V** thread of the same pitch is indicated by the dotted lines. It has straight sides that form an angle of 55 degrees with each other, and the point and the root are rounded. The curve r at the root and at the point is part of a circle that has a radius equal to .137 times the pitch of the thread. The sides of the threads are tangent to the circles

TABLE VI

BRITISH STANDARD, OR WHITWORTH, SCREW THREADS

Diameter of Bolt Inch	Number of Threads per Inch	Diameter of Bolt Inches	Number of Threads per Inch	Diameter of Bolt Inches	Number of Threads per Inch	Diameter of Bolt Inches	Number of Threads per Inch
$\frac{1}{4}$	20	$\frac{7}{8}$	9	2	$4\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{4}$
$\frac{5}{16}$	18	$\frac{15}{16}$	9	$2\frac{1}{8}$	$4\frac{1}{2}$	$3\frac{3}{8}$	$3\frac{1}{4}$
$\frac{3}{8}$	16	1	8	$2\frac{1}{4}$	4	$3\frac{1}{2}$	$3\frac{1}{4}$
$\frac{7}{16}$	14	$1\frac{1}{8}$	7	$2\frac{3}{8}$	4	$3\frac{5}{8}$	$3\frac{1}{4}$
$\frac{1}{2}$	12	$1\frac{1}{4}$	7	$2\frac{1}{2}$	4	$3\frac{3}{4}$	3
$\frac{9}{16}$	12	$1\frac{3}{8}$	6	$2\frac{5}{8}$	4	$3\frac{7}{8}$	3
$\frac{5}{8}$	11	$1\frac{1}{2}$	6	$2\frac{3}{4}$	$3\frac{1}{2}$	4	3
$\frac{11}{16}$	11	$1\frac{5}{8}$	5	$2\frac{7}{8}$	$3\frac{1}{2}$		
$\frac{3}{4}$	10	$1\frac{3}{4}$	5	3	$3\frac{1}{2}$		
$\frac{13}{16}$	10	$1\frac{7}{8}$	$4\frac{1}{2}$	$3\frac{1}{8}$	$3\frac{1}{2}$		

drawn at the root and the point. The depth of the British Standard thread is .64 times that of the sharp, or **V**, thread of equal pitch, and it is therefore the stronger. Table VI gives the number of threads per inch corresponding to a certain diameter of bolt having British Standard threads.

21. Automobile Threads.—The Society of Automotive Engineers has adopted a standard of screw threads that is better suited to automobile work than either the United States Standard or the **V** thread. The screws used in automobile work are of finer pitch than the United States Standard, because the screws and bolts are of as small diameter as they may be made with safety, and the fine thread does

TABLE VII

SOCIETY OF AUTOMOTIVE ENGINEERS' STANDARD SCREWS

Diameter of Screw Inches	Number of Threads per Inch	Diameter at Root of Thread Inches	Pitch Inch
$\frac{1}{4}$	28	.2036	.0357
$\frac{5}{16}$	24	.2584	.0417
$\frac{3}{8}$	24	.3209	.0417
$\frac{7}{16}$	20	.3726	.0500
$\frac{1}{2}$	20	.4351	.0500
$\frac{9}{16}$	18	.4903	.0556
$\frac{5}{8}$	18	.5528	.0556
$\frac{11}{16}$	16	.6063	.0625
$\frac{3}{4}$	16	.6688	.0625
$\frac{7}{8}$	14	.7822	.0714
1	14	.9072	.0714
$1\frac{1}{8}$	12	1.0168	.0833
$1\frac{1}{4}$	12	1.142	.0833
$1\frac{3}{8}$	12	1.2668	.0833
$1\frac{1}{2}$	12	1.3918	.0833

not need to be cut so deep as the coarser pitch, thus making the screw stronger. Another reason is that most of the threads are cut in hard, tough materials that do not require as coarse a pitch of thread as does cast iron. The automobile thread is of the same shape as the United States Standard. It was formerly known as the A. L. A. M. thread, or Association of Licensed Automobile Manufacturers' Standard thread. The number of threads per inch corresponding to each size of screw is shown in Table VII. A screw of $\frac{7}{8}$ inch diameter and having 18 threads is the standard spark plug size.

22. Metric, or International, Thread.—This form of thread is shown in Fig. 12, and is the same as the United States Standard, except that the root is rounded and forms a clearance at the top of the thread both on the bolt *a* and in the nut *b*, as shown. The amount of this clearance is

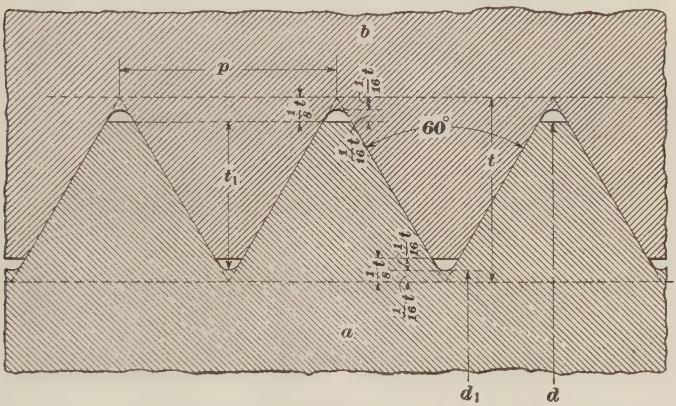


FIG. 12

left to the manufacturer, but it is not to exceed one-sixteenth of the height t. The depth t_1 of the thread may be found by multiplying the pitch p by .7036, or $t_1 = .7036 \times p$.

EXAMPLE.—Required, the depth of a metric thread cut on a bolt having a diameter of 30 millimeters.

SOLUTION.—According to Table VIII, a bolt of 30 millimeters diameter has a thread pitch of 3.5 millimeters, or $p = 3.5$ The depth of the thread is $.7036 \times 3.5 = 2.46$ millimeters. Ans.

23. Briggs Standard Pipe Thread.—The Briggs Standard pipe thread is shown in Fig. 13 (*a*). Its sides form an angle of 60 degrees with each other and with the center line of the pipe. The point and root are slightly rounded, as shown, making the depth of the thread slightly less than that of the **V** thread, or 0.8 times the pitch in inches. Owing to the difficulty of cutting the thread with rounded point and root on a lathe, it is usually cut with a sharp root and slightly flat point, as shown in Fig. 13 (*b*). In this case its depth is 0.833 times the pitch in inches. The threaded part of a

TABLE VIII

METRIC STANDARD SCREW THREADS

Diameter of Bolt		Pitch		Diameter at Root of Thread		Width of Flat	
Millimeters	Inches	Millimeters	Inch	Millimeters	Inches	Millimeter	Inch
3	.1181	.5	.0197	2.35	.0925	.06	.0024
4	.1575	.75	.0295	3.03	.1193	.09	.0035
5	.1969	.75	.0295	4.03	.1587	.09	.0035
6	.2362	1.0	.0394	4.70	.1850	.13	.0051
7	.2756	1.0	.0394	5.70	.2244	.13	.0051
8	.3150	1.0	.0394	6.70	.2638	.13	.0051
8	.3150	1.25	.0492	6.38	.2512	.16	.0063
9	.3543	1.0	.0394	7.70	.3031	.13	.0051
9	.3543	1.25	.0492	7.38	.2906	.16	.0063
10	.3937	1.5	.0591	8.05	.3169	.19	.0075
11	.4331	1.5	.0591	9.05	.3563	.19	.0075
12	.4724	1.5	.0591	10.05	.3957	.19	.0075
12	.4724	1.75	.0689	9.73	.3831	.22	.0087
14	.5512	2.0	.0787	11.40	.4488	.25	.0098
16	.6299	2.0	.0787	13.40	.5276	.25	.0098
18	.7087	2.5	.0984	14.75	.5807	.31	.0122
20	.7874	2.5	.0984	16.75	.6594	.31	.0122
22	.8661	2.5	.0984	18.75	.7382	.31	.0122
24	.9449	3.0	.1181	20.10	.7913	.38	.0150
26	1.0236	3.0	.1181	22.10	.8701	.38	.0150
27	1.0630	3.0	.1181	23.10	.9094	.38	.0150
28	1.1024	3.0	.1181	24.10	.9488	.38	.0150
30	1.1811	3.5	.1378	25.45	1.0020	.44	.0173
32	1.2598	3.5	.1378	27.45	1.0807	.44	.0173
33	1.2992	3.5	.1378	28.45	1.1201	.44	.0173
34	1.3386	3.5	.1378	29.45	1.1594	.44	.0173
36	1.4173	4.0	.1575	30.80	1.2126	.50	.0197
38	1.4961	4.0	.1575	32.80	1.2913	.50	.0197
39	1.5354	4.0	.1575	33.80	1.3307	.50	.0197
40	1.5748	4.0	.1575	34.80	1.3701	.50	.0197
42	1.6535	4.5	.1772	36.15	1.4232	.56	.0220
44	1.7323	4.5	.1772	38.15	1.5020	.56	.0220
45	1.7717	4.5	.1772	39.15	1.5413	.56	.0220
46	1.8110	4.5	.1772	40.15	1.5807	.56	.0220
48	1.8898	5.0	.1969	41.51	1.6342	.63	.0248
50	1.9685	5.0	.1969	43.51	1.7130	.63	.0248
52	2.0472	5.0	.1969	45.51	1.7917	.63	.0248
56	2.2047	5.5	.2165	48.86	1.9236	.69	.0272
60	2.3622	5.5	.2165	52.86	2.0811	.69	.0272
64	2.5197	6.0	.2362	56.21	2.2130	.75	.0295
68	2.6772	6.0	.2362	60.21	2.3705	.75	.0295
72	2.8346	6.5	.2559	63.56	2.5024	.81	.0319
76	2.9921	6.5	.2559	67.56	2.6598	.81	.0319
80	3.1496	7.0	.2756	70.91	2.7917	.88	.0346

pipe is tapered $\frac{3}{4}$ inch per foot. When pipe threads are cut with dies, there are several incomplete threads back of the perfect ones, as shown in Fig. 13 (*c*). The illustration

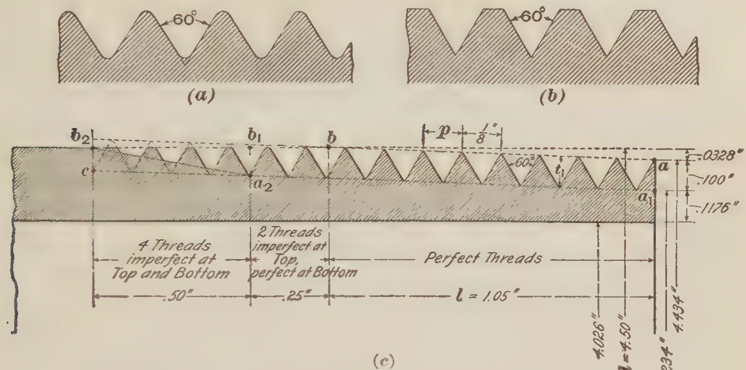


FIG. 13

also shows the dimensions of the threaded part of a 4-inch pipe, taken from Table IX.

24. Buttress Thread.—This thread is variously known as the *trapezoidal*, *bastard*, *ratchet*, and *Harvey grip thread*. The

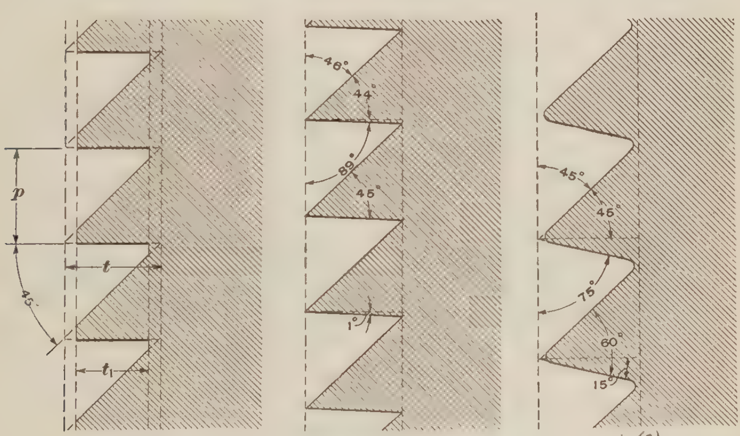


FIG. 14

ordinary form of buttress thread is shown in Fig. 14 (*a*). Its face is perpendicular to the axis of the screw and the back is

TABLE IX

BRIGGS STANDARD STEAM, GAS, AND WATER PIPE

Sizes of Pipes Inches	Threads per Inch	Actual External Diameter Inches	Actual Internal Diameter Inches	Total Length of Thread Inches	Length of Perfect Thread Inches	Diameter of Tap Drill Inches	Diameter at End of Pipe Inches	
							Outside	At Bottom of Thread
$\frac{1}{8}$	27	.405	.270	.41	.19	$\frac{21}{64}$	.393	.334
$\frac{1}{4}$	18	.540	.364	.62	.29	$\frac{29}{64}$	.522	.433
$\frac{3}{8}$	18	.675	.494	.63	.30	$\frac{19}{32}$	.656	.568
$\frac{1}{2}$	14	.840	.623	.83	.39	$\frac{23}{32}$	.815	.701
$\frac{3}{4}$	14	1.050	.824	.84	.40	$\frac{15}{16}$	1.025	.911
1	$11\frac{1}{2}$	1.315	1.048	1.03	.51	$1\frac{3}{16}$	1.283	1.144
$1\frac{1}{4}$	$11\frac{1}{2}$	1.660	1.380	1.06	.54	$1\frac{15}{32}$	1.626	1.488
$1\frac{1}{2}$	$11\frac{1}{2}$	1.900	1.611	1.07	.55	$1\frac{23}{32}$	1.866	1.727
2	$11\frac{1}{2}$	2.375	2.067	1.10	.58	$2\frac{3}{16}$	2.339	2.200
$2\frac{1}{2}$	8	2.875	2.468	1.64	.89	$2\frac{11}{16}$	2.819	2.620
3	8	3.500	3.067	1.70	.95	$3\frac{5}{16}$	3.441	3.241
$3\frac{1}{2}$	8	4.000	3.548	1.75	1.00	$3\frac{13}{16}$	3.938	3.738
4	8	4.500	4.026	1.80	1.05	$4\frac{7}{32}$	4.434	4.234
$4\frac{1}{2}$	8	5.000	4.508	1.85	1.10	$4\frac{21}{32}$	4.931	4.731
5	8	5.563	5.045	1.91	1.16	$5\frac{15}{64}$	5.491	5.291
6	8	6.625	6.065	2.01	1.26	$6\frac{1}{4}$	6.546	6.346
7	8	7.625	7.023	2.11	1.36	$7\frac{5}{16}$	7.540	7.340
8	8	8.625	7.982	2.21	1.46	$8\frac{5}{16}$	8.534	8.334
9	8	9.625	8.937	2.32	1.57	$9\frac{5}{16}$	9.527	9.327
10	8	10.750	10.019	2.43	1.68	$10\frac{5}{16}$	10.645	10.445

NOTE.—The taper of the threaded part is $\frac{3}{4}$ inch per foot.

inclined 45 degrees. The point and root are flat, giving a depth t_1 of $\frac{3}{4}$ of a sharp-cornered thread. The depth t is equal to the pitch p. In the Harvey grip form shown in (b), the face has a slope of 1 degree and the back 44 degrees, making 45 degrees between the two sides. For the breech blocks of guns the face has a slope of 15 degrees and the back 45 degrees, making a total angle of 60 degrees, and the thread is rounded off at the point and root, as shown in (c).

25. Knuckle Thread.—A variation of the square thread is the knuckle thread, a section of which is shown in Fig. 15. In this type, the top and the root of the thread are rounded off, thus not only increasing its strength but also its friction surface. The knuckle thread is especially adapted to withstand rough usage.

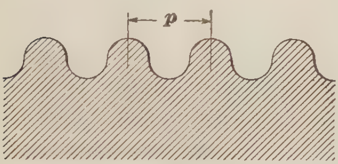


FIG. 15

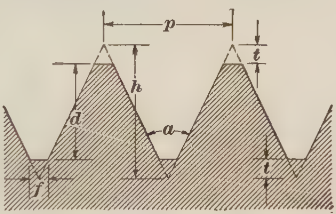


FIG. 16

26. Löwenherz Thread.—The Löwenherz thread is intended for the fine screws of instruments and is based on the metric system. It has been adopted by the Bureau of Standards, as there has been a lack of uniformity in the small screws in instruments made in this country. The distance h in Fig. 16, from point to point, is equal to the pitch p, and the top and bottom of the thread are flat, the dimensions t and f being equal to $\frac{1}{8}$ of the pitch. The angle a between the sides equals 53 degrees 8 minutes, and the depth d of the thread is equal to $\frac{3}{4}$ p.

THREADING TOOLS

27. Tool for Cutting V Threads.—The threading tool for V threads is shown in Fig. 17. It is ground flat on the top face, and the front faces and cutting edges NS and GK

are ground to form an angle of 60 degrees. This angle is tested by the center gauge shown in Fig. 18, which has two 60-degree notches cut in it. The angle of the point is also 60 degrees. The point of the tool is set in the notch of the

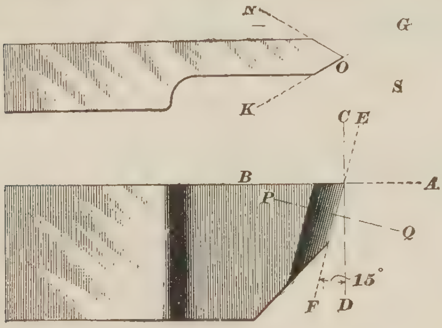


FIG. 17

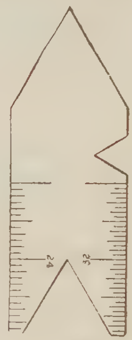


FIG. 18

gauge, *which should lie flat in line with the top surface of the tool* in the line BA, Fig. 17. It is a mistake to hold the gauge in the line PQ square with the front edge EF, as the angle on PQ is $61\frac{3}{4}$ degrees when the clearance angle is 15 degrees.

The angle of front rake, or clearance, is 15 degrees, as indicated by the angle between the lines CD and EF, Fig. 17. A tool for heavy work is shown in Fig. 19. This has the disadvantage that it grows thicker each time it is ground, thus making it more difficult to cut threads close to a shoulder. Very often the tool is made offset, as shown in Fig. 20, for use in threading pieces whose shape would cause the tool carriage to strike the piece if a straight tool were used as, for instance, in threading a very short spindle on which a relatively large wheel is mounted.

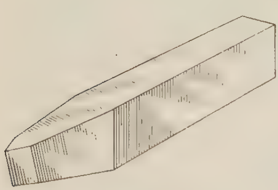


FIG. 19


FIG. 20

28. Multiple-Tooth Circular Threading Tool.—As several cuts are necessary to produce a thread, the multiple-tooth tool shown in

Fig. 21 has been devised. The cutter *a* has ten teeth on its circumference, each one formed to cut deeper than the preceding one, and gives the thread its actual width to the full depth of its cut. For instance, in Fig. 22, the first tooth cuts the full width of the thread down to the line *1*, the second cuts to the line *2*, and so on until the tenth tooth cuts to the bottom. As the cutting is distributed over ten teeth, the sharp point of the 10th, or finishing, tooth is not

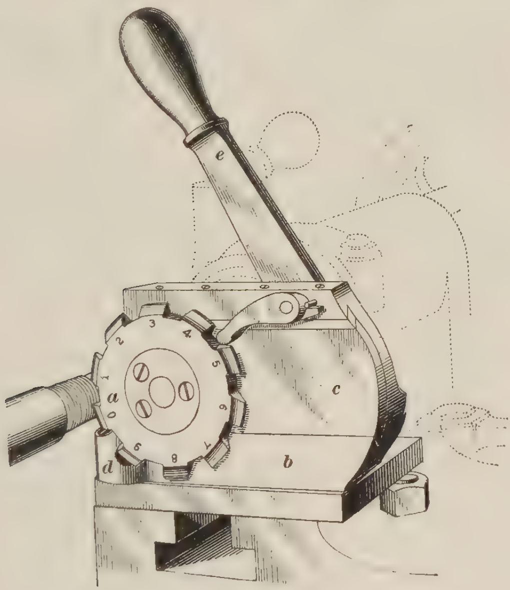


Fig. 21

in use on every cut, as is the case with the ordinary tool. Therefore, the work can run at a higher speed.

29. Tool for Cutting United States Standard Threads. The United States Standard threading tool, Fig. 23, is first ground to fit the 60-degree notch in the gauge, Fig. 5, and then the point is ground off to fit the flat in the gauge, Fig. 24, for the pitch of thread to be cut. The width of the flat must measure $\frac{1}{8}$ the pitch in inches, and to get this width the sharp point must be ground off a distance equal to $\frac{1}{8}$ the height of

a **V** thread of the same pitch. Each pitch of thread requires a different width of tool point.

30. It is difficult to measure the width of the United States tool point except by the use of a gauge. The indirect

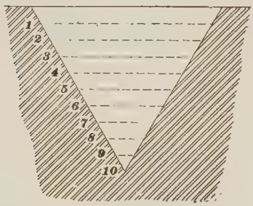


Fig. 22

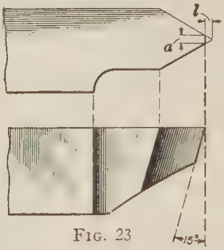


Fig. 23

method of measuring the width a, Fig. 23, of the point is to caliper the length l that must be ground off the **V** tool. This length is equal to .1082 multiplied by the pitch. Thus, for a pitch of $\frac{1}{4}$ inch, grind off a length of $.1082 \times \frac{1}{4} = .027$ inch, in order to give the tool point the required flatness of $\frac{1}{32}$ inch.

For convenience the last column of Table II gives the calculated lengths of l. To apply this measure, caliper either the full length of the **V** tool or some part of it. A clamp attached to the shank an inch or so from the point serves as a good distance marker. Then reduce the caliper setting by the dimension given in the last column of Table II, and grind away the tool point until the length calipers correctly. A clearance of 15 degrees is given to the tool, and if a

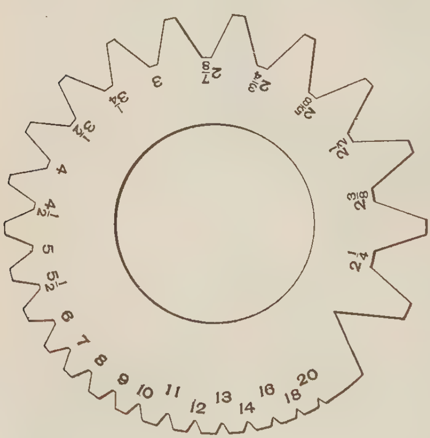


Fig. 24

tool gauge, such as is shown in Fig. 24 is not available, the tool angle can be ground to the center gauge, Fig. 5, and the flat end gauged in a corresponding United States Standard tap.

31. Tool for Cutting Square-Threads.—A square thread with a section of the tool used for cutting it set in its working position is shown in Fig. 25 (*a*). The square-thread tool is square-pointed, with its top face sloping slightly downwards and sidewise in the direction that the tool is feeding while cutting, as shown at *a*. The top side slope is given so that the top face will make equal angles with the two sides of the thread. The cutting part of the tool is short, as shown in the view (*b*)

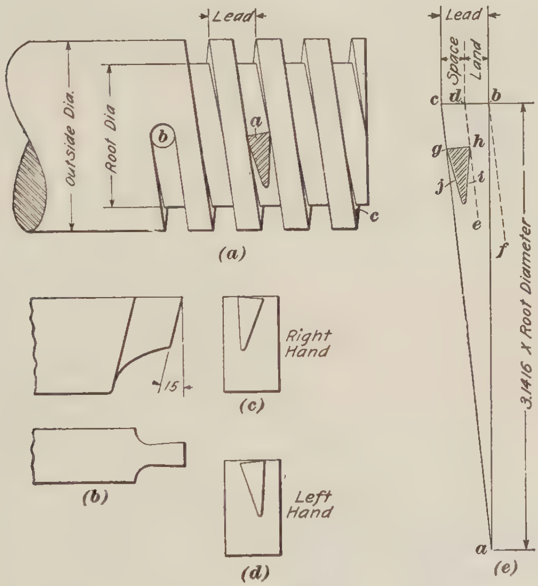


FIG. 25

to give stiffness, and it is set at an angle with the vertical side of the shank of the tool so that the cutting part will follow the groove or space being cut between the threads without bearing against either side, as may be seen in view (*a*). This inclination is called the *angle of top side rake*, and varies with every pitch and diameter of square thread. A right-hand tool is shown at (*c*), and a left-hand one in (*d*).

32. Angle of Top Side Rake for Square-Thread Tool. The angle of top side rake is found by drawing a straight line

$a\,b$, Fig. 25 (e), equal in length to the circumference of the bolt at the root of the thread, and at one end a perpendicular $b\,c$ equal to the lead of the thread. Then the points a and c are joined by a straight line $a\,c$. The angle $c\,a\,b$ is the angle of top side rake. The lead is equal to the sum of the width of the thread and the width of the space. The distance $c\,d$ is made equal to the width of the space, and the dotted lines $d\,e$ and $b\,f$ are drawn parallel to the slanting line $a\,c$. The distance $g\,h$ between the lines $a\,c$ and $d\,e$ is the shortest distance between the threads and represents the width of the tool at the cutting edge. The tool is shown in section in its correct angu-

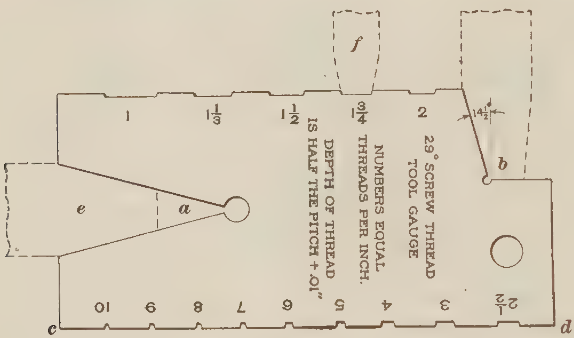


Fig. 26

lar position at i. In addition to its angle of top side rake, it should have clearance on each side, as at j, so that it will not rub against the sides of the groove, which are represented by the lines $a\,c$ and $e\,d$. The angle of clearance should be 15 degrees, as shown in view (b). The point of the tool, for a distance of from $\frac{1}{16}$ to $\frac{1}{8}$ inch back from the cutting edge, should have the correct width of the thread space, and back of this point should be narrower, so as to cut a clean thread. A roughing tool slightly narrower than the finishing tool may be used to rough out a square thread to the correct root diameter.

Example.—Find the angle of top side rake for a tool to cut a square thread of $\frac{1}{2}$ inch pitch on a screw 2 inches in diameter.

Solution.—The method is shown by the diagrams in Fig. 25 (a) and (e), which are half size. The pitch is $\frac{1}{2}$ in., and the width of the space is

half the pitch, or $\frac{1}{4}$ in., which is also the depth of the space. The root diameter is equal to the outside diameter minus twice the depth of the space, or $2-(2\times\frac{1}{4})=2-\frac{1}{2}=1\frac{1}{2}$ in. The distance $a\,b$ in (e) is therefore made $3.1416\times 1\frac{1}{2}=4.71$ in. The distance $b\,c$ is laid off vertically equal to $\frac{1}{2}$ in., or the lead, and the line $c\,a$ is drawn. Then the angle $c\,a\,b$ is the required angle of top side rake to be given to the tool. Ans.

33. Tool for Cutting Acme Threads.—The Acme thread tool is ground or filed to the 29-degree **V** notch a in the thread-tool gauge shown in Fig. 26. Its point is then made flat to fit the width of the slot opposite the number denoting the pitch of thread to be cut, as at f. The width of the point of the tool equals the pitch multiplied by .3707 and .0052 subtracted from the product. The depth of the thread is half the pitch plus 0.01 inch. The end of the gauge opposite the slot a has a $14\frac{1}{2}$-degree angle b that is used in setting the tool. The back edge $c\,d$ of the gauge is held against the work or the dead spindle and the tool is adjusted to fit the angle b in the front of the gauge.

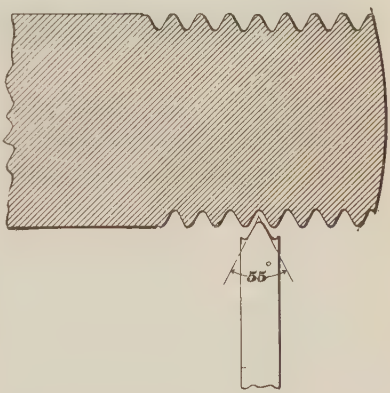


FIG. 27

EXAMPLE.—How wide should the point of a threading tool be ground to cut an Acme thread of 5 threads per inch?

SOLUTION.—The pitch of the thread is $\frac{1}{5}$, or .20 inch. The width of the point of the tool equals $(.20\times .3707)-.0052=.0689$ inch. Ans.

34. Tool for Cutting British, or Whitworth, Threads. The tool for cutting British Standard threads is much more difficult to make than the tool for sharp or flat threads, owing to the curved point and root of the thread. Each pitch or lead of thread requires a separate tool. In Fig. 27 is shown a section of the tool as it is applied to the work. It is best formed by using a hob, such as shown in Fig. 28, which is an accurately threaded, hardened, and tempered screw of the required diameter and pitch or lead of thread. This hob is

fluted, or grooved lengthwise, as shown to form cutting edges. The teeth formed by the flutes are backed off, after which the hob is hardened and tempered. A dog is clamped on the hob, which is held between the lathe centers while the tool blank is held in the tool post. As the hob revolves, the tool blank is fed up to it; at the same time it is fed along by the lead screw.

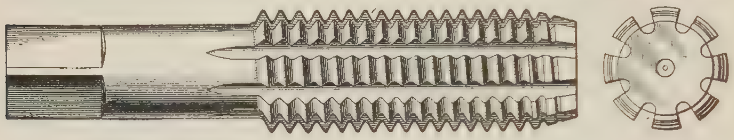
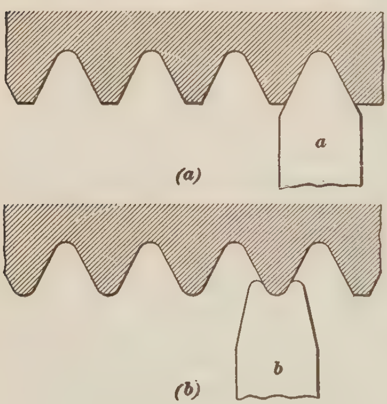


FIG. 28

By repeating these operations, as in cutting a screw, the blank is soon formed into a threading tool. It is then hardened and tempered, and must be ground on the top face to be sharpened.

Another method of cutting the British Standard thread is to use two tools as shown in Fig. 29. The tool *a* forms the sides of the thread and the curved root, and the tool *b* is



used to round off the flat points.

FIG. 29

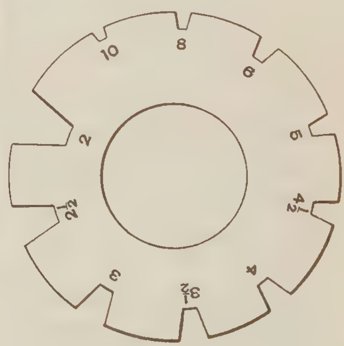


FIG. 30

35. Tool for Cutting Worm Threads.—The worm-threading tool is similar to the tool for the Acme thread, previously described, but it is not so wide at the point. It is made about one-third deeper than the Acme tool for a thread of the same pitch, to increase the wearing surface. The tool for cutting the worm thread must have enough side rake to

follow the lead of the thread being cut. It should be ground to fit the gauge shown in Fig. 30. The figures on the gauge correspond to the number of threads per inch on the worm.

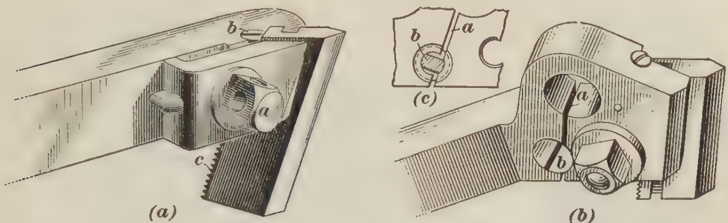


Fig. 31

36. Inserted-Blade Threading Tools.—Various forms of tool holders have been designed for threading tools. Fig. 31 (*a*) shows one of these forms for **V** threads. The tool is accurately made and ground so that the front faces form such an angle with each other when the top face is ground flat that the angle of the cutting edges will be 60 degrees. The inserted blades are sharpened by grinding the top faces. Tool holders are made for cutting square threads, blades of various thicknesses being used to cut the various pitches of threads. The blade is clamped to the holder by the square-headed screw *a*, and may be adjusted vertically by the screw *b* that engages the thread *c* on the back of the blade.

For cutting fine spreads the spring type of holder, shown in (*b*), is sometimes used. The slot *a* cut through all but the top

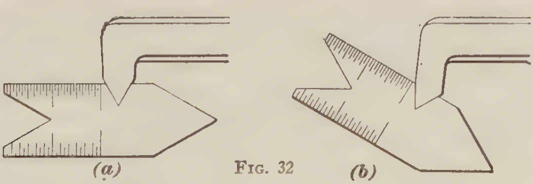


Fig. 32

of the holder allows the tool a slight spring, which is of advantage in fine threading. The screw *b* has a flat side, which is set parallel with the slot when the springing action is desired.

By turning the screw 90 degrees the slot is closed by the screw and there is no chance for the tool to spring, and the holder becomes, then, similar to the rigid holder, shown in (*a*).

37. Standard Single-Pointed Inside-Threading Tool. Lathe inside-threading tools are similar to lathe boring tools in that the cutting point is located on the side of a bar that reaches into the hole. The **V**-thread tool is shown in Fig. 32 (*a*). The point should be ground to fit the gauge when the side of the gauge is nearly parallel to the shank of the tool, as shown. If the point is ground as in Fig. 32 (*b*), the tool can be used only on thin work, or where the hole is quite large; otherwise, the shank will strike the edge of the hole, as shown in Fig. 33, and the thread will be spoiled.

Fig. 33

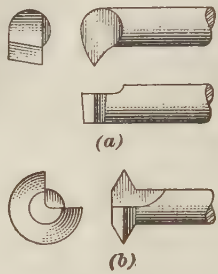


Fig. 34

Inside-threading tools are also made to use with holders, such as are used for turning and boring tools. Thus, in Fig. 34 is shown at (*a*) a toolholder threading tool of standard type, and in (*b*) a circular form of threading tool to be held in a special holder that is clamped in the tool post.

38. Multiple-Pointed Threading Tools.—The great majority of threaded parts are not cut with a single-pointed tool. Internal threads are often cut with taps, external threads with dies. Taps and dies are really nothing but a number of single-pointed tools set side by side and the proper distance apart. A multiple-pointed threading tool for external threads, also called a *machine chaser*, is shown in Fig. 35. It is cut with a hob, as

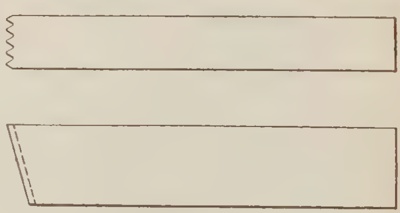


Fig. 35

described for the Whitworth tool, and is ground on the top face only. It is used both for roughing and finishing screw threads.

39. Multiple-Pointed Lathe Tools for Cutting Inside Threads.—A straight or flat form of multiple-pointed threading tool, or chaser, for internal threads, is shown in Fig. 36, and a circular form at *a*, in Fig. 37. The latter is held in the tool post by using a holder *b* with a set-

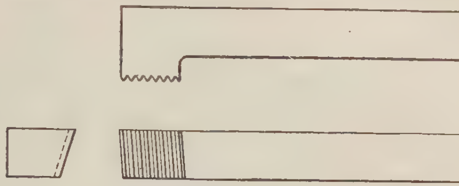


FIG. 36

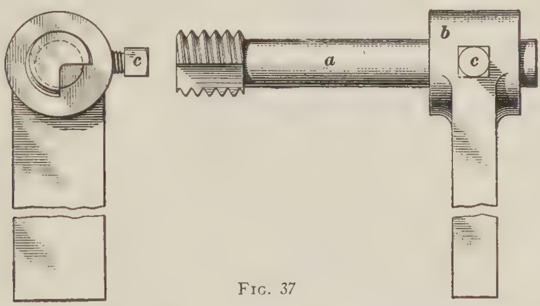


FIG. 37

screw *c*. The flat form is sharpened by grinding on the top face, and the circular form by grinding the face radially.

40. Hand Chasers for Threading Brass.—Hand chasers, such as is shown in Fig. 38, are sometimes used to cut threads in a lathe. The tool at (*a*) is for cutting external threads, and that shown at (*b*) for internal threads. Such tools are especially useful for threading brass work. Considerable skill is necessary in order to use hand chasers with success.

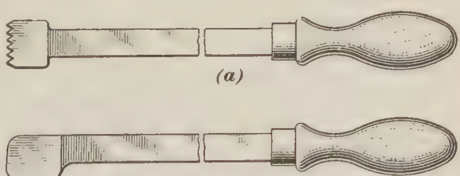


FIG. 38

THREAD CUTTING PRACTICE ON ENGINE LATHES

CHANGE GEARS FOR THREAD CUTTING

41. Adapting Engine Lathe for Screw Cutting.—The engine lathe is made suitable for cutting threads by four devices to produce motion; namely, a lead screw to move the carriage along the bed, a set of *change gears* to make the lead screw turn faster or slower than the spindle, a feed-gear reversing mechanism, and a means of reversing the motion of the spindle and the work. The lead screw *i*, Fig. 39, is driven at any required speed with respect to the spindle speed, through a train of fixed gears *b* to *d*, and change gears *e* to *g* from the live spindle driven by the cone *a*. It usually has 2, 3, 4, 5, 6, or 8 threads per inch.

42. Reversing Mechanisms.—The reversing gears *h* and *c*, Fig. 39, are pinned to an arm attached to the lever *j*. As shown, gear *c* connects the spindle gear *b* to the stud gear *d*. When the lever *j* is pushed down, the gear *c* is separated from *b* and gear *h* is added to the train and connects with *b*, thus giving a reversed motion to the lead screw *i* in changing from right-hand to left-hand threading. The direction of rotation of the work is reversed by the counter-shaft or by operating the reversing gear in the main drive of the geared head, to return the carriage and the tool to the starting point for a fresh cut. The gear *f* is an idler used to fill the space between the change gears *e* and *g*.

43. Change-Gear Stack.—The ordinary engine lathe has a set, or stack, of change gears, which are made in a regular order of sizes, the smallest having about twenty and the largest about one hundred and twenty teeth. The various gears in the set vary by a regular number of teeth, as 4, 5, or 6; that is, if a set of gears has 20, 24, 28, 32, 36 teeth, etc., the gears are said to vary by 4, and the number of teeth in each gear is divisible by 4. If the gears have 18, 24, 30, 36, 42, etc., teeth, they are said to vary by 6, and the number of teeth in each gear in the set is divisible by 6. Each stack of change gears

also has two gears, near the middle of the range, that are of equal size, as two gears of 44, or 48 teeth, which are used to cut a thread of the same pitch as the lead screw.

44. Sizes of Fixed and Change Gears.—The number of turns made by the spindle, or work to be threaded, for each turn of the lead screw is regulated by the sizes of the fixed gears *b* and *d*, Fig. 39, and the change gears *e* and *g* used on the

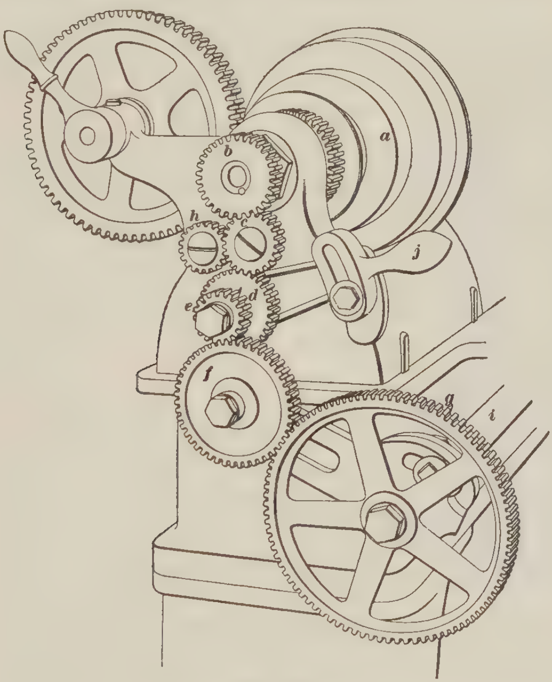


FIG. 39

head of the lathe. If the spindle and stud gears, *b* and *d*, are equal and two change gears *e* and *g* of the same size are placed on the stud and lead screw, the lead screw will make the same number of turns as the spindle and the screw thread cut will have the same pitch as the lead screw. On most lathes the stud gear *d* turns at the same speed as the spindle, so that any change of speed of the lead screw depends entirely on the change gears *e* and *g*.

45. On some lathes the stud gear *d* runs at half the spindle speed, while other lathes have some other fixed gear change of speed. The speed change in the fixed gears must be known before the sizes of the change gears *e* and *g* to cut any given thread can be calculated. The lathe operator can easily find the speed change of the fixed gears by placing equal gears at *e* and *g* and measuring the distance the carriage moves during ten revolutions of the spindle and dividing it by ten. The reason for using so many revolutions is to average, or reduce, the errors. Be sure that all backlash, or play between the parts, is taken up before making the measurement.

46. Lead of the Lathe.—The distance that the carriage travels along the bed during one complete turn of the spindle, or work, when gears of the same sizes are used at *e*, Fig. 39, on the stud and *g* on the lead screw, is the *lead of the lathe*. If the gear *b* on the spindle is of the same size as the gear *d* on the stud, so that they turn at the same speed, the lead of the lathe is equal to the pitch or lead of the lead screw; but if the gear *d* on the stud is twice the size of the gear *b* on the spindle, the lead of the lathe will be only half as great as before. When the fixed gears *b* and *d* on the spindle and on the stud are equal, the lathe is said to be geared 1 to 1; but when the stud gear *d* has twice as many teeth as the spindle gear *b*, the lathe is said to be geared 1 to 2. When the spindle gear *b* has twice as many teeth as the gear *d*, the lathe is said to be geared 2:1.

47. Effective Number of Threads per Inch on Lead Screw. If a lathe is geared 1 to 1 and has a lead of $\frac{1}{4}$ inch, the lead screw has 4 threads per inch. If the same lathe were geared 1 to 2, the lead of the lathe would be $\frac{1}{8}$ inch, and the effect would be the same as though the lead screw had 8 threads per inch and the lathe was geared 1 to 1. The effective number of threads, or change of speed of the lead screw, must be considered when the fixed gears on the lathe are other than 1 to 1; that is, the speed of the lead screw and the distance the carriage moves for each turn of the spindle depends on both the fixed-gear ratio and the change-gear ratio.

48. Index Plate.—An index plate, Fig. 40, is a cast-brass plate attached to the headstock of a lathe, on which are indicated the change-gear combinations to be used when cutting threads of various pitches. The plate shown is used on a lathe having a fixed gear ratio of 1 to 1 and a lead screw with 8 threads per inch. The first column gives the number of threads per inch to be cut. The second column gives the size of the gear to use on the stud. The third column gives the gear that must be placed on the lead screw.

For cutting odd threads such as 11, $11\frac{1}{2}$, and 13, special gears not in the regular order of the stack are needed. For cutting a large number of threads per inch, such as 22 to 40, an extra pair of gears is used, as shown by 1–2 in the third column. The 1–2 means that the second gear of the pair is twice the size of the first one. The use of a second, or *compound*, pair of gears is explained later.

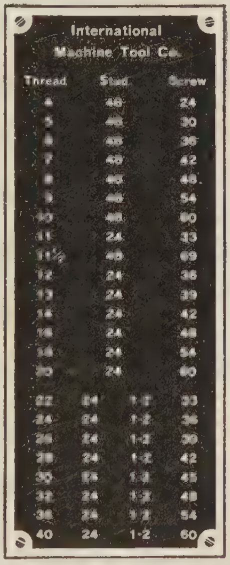


FIG. 40

49. Quick-Change Gearing.—Many engine lathes are equipped with quick-change gearing. An example of this type of change gearing is described in the Instruction Paper on *Engine Lathes*. By the use of quick-change gearing, the change gears needed for cutting any pitch of thread do not have to be put on to the stud and lead screw. The change is made by a simple movement of one or more levers.

50. Change-Gear Gear-Box.—The arrangement of the change gears in the gear-box on the lathe, shown in Fig. 41, will be seen in Fig. 42. All the change gears are on a shaft in the gear-box *g* seen on the front of the lathe directly below the headstock. To change from one set of gearing to another, the knob *a*, which moves in the large diagonal slot in the

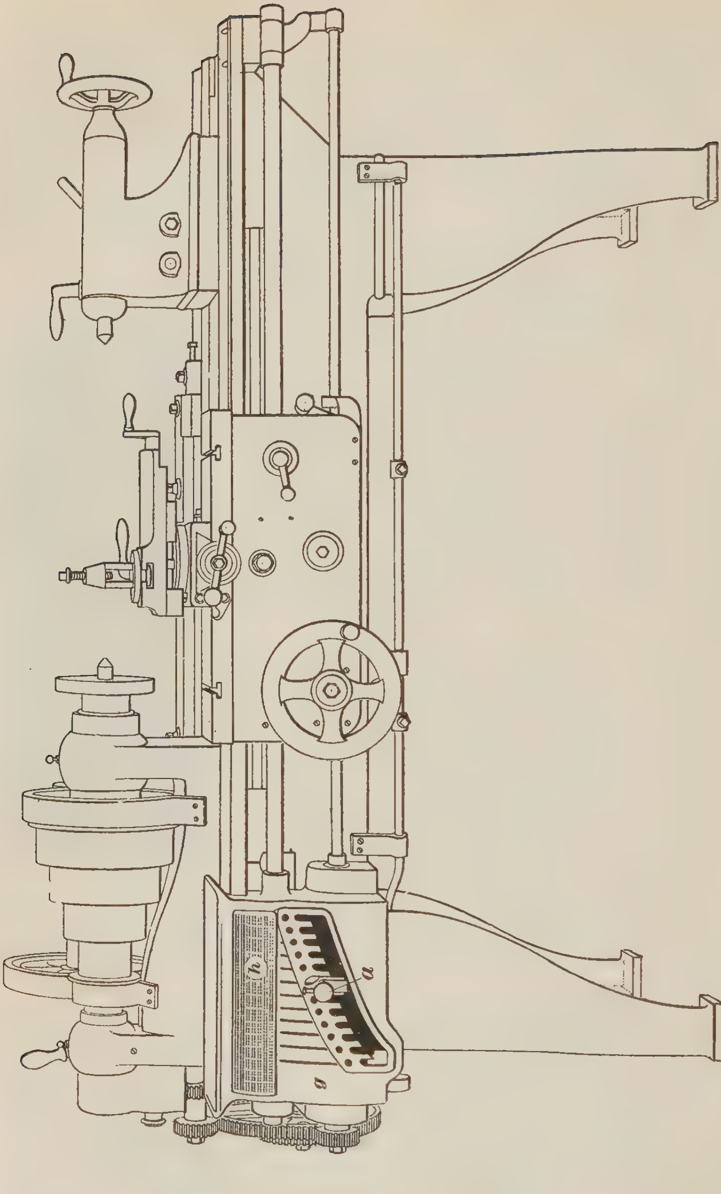


Fig. 41

front of the gear-box, is moved to a position indicated by the table or index plate *h* on the box. The back of the gear-box is shown in Fig. 42 with the lead screw *a* projecting from the left-hand side. Twelve gears *b* are keyed on the lead screw inside the gear-case. A sliding gear *c* and an idler *d* carried on a yoke can be moved to engage with any one of the gears in the lead-screw cone, giving twelve different speeds to the lead screw. At the right of the gear-box is the compounding box *e* containing gears that give three different speed changes to the shaft and the sliding gear *c* and when

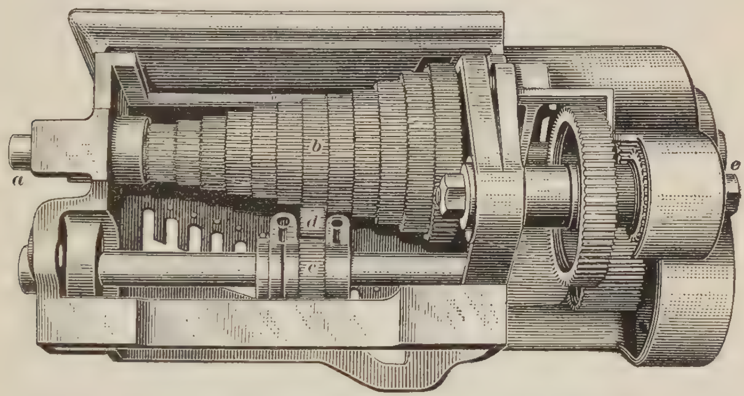


FIG. 42

combined with the twelve gears on the lead screw give thirty-six speeds or threads that can be cut.

51. Calculating Change Gears.—In case the index plate is omitted, or the lathe has no quick-change set, or when it is desired to cut a thread which is not given on the plate, it becomes necessary to calculate the sizes of the change gears that must be used. For a single pair of change gears, as shown at *e* and *g* in Fig. 39, and known as *simple gearing*, the following rule may be used to calculate the sizes of the gears where the fixed gears are 1 to 1.

Rule.—*Form a fraction whose numerator is the number of threads per inch on the lead screw of the lathe, and whose denominator is the number of threads per inch to be cut; then multiply*

both terms of this fraction by any number that will give gears of practical sizes, and which, if possible, can be selected from the stack furnished with the lathe. If the first trial multiplier does not give gears convenient to use, repeat the operation with one or more other multipliers.

The gear having the number of teeth corresponding to the numerator of the fraction thus found is the driver and should be placed on the stud, and the gear corresponding to the denominator is the follower, or driven gear, and should be placed on the lead screw.

52. Examples of Simple Change-Gear Calculations.—To illustrate how the rule in Art. **51** is applied in solving problems, the following examples and solutions are given:

EXAMPLE 1.—A lathe that is geared 1 to 1 has a lead screw with 4 threads per inch, and the gears in the gear-stack vary by 6 teeth from 18 to 120. What simple change gears should be used to cut a screw with 8 threads per inch?

SOLUTION.—According to the rule, the ratio of the change gears is, $\frac{4}{8}$, and $\frac{4}{8}\times\frac{6}{6}=\frac{24}{48}$, indicating that a gear having 24 teeth should be placed on the stud and one having 48 teeth on the lead screw. Ans.

EXAMPLE 2.—A lathe that is geared 1 to 1 has a lead screw with 4 threads per inch, and the gears in the stack vary by 5 teeth from 20 to 120. What simple change gears may be used to cut $2\frac{1}{2}$ threads per inch on the work?

SOLUTION.—According to the rule, the ratio of the change gears is $\frac{4}{2\frac{1}{2}}$, and $\frac{4}{2\frac{1}{2}}\times\frac{10}{10}=\frac{40}{25}$, indicating that a gear having 40 teeth should be placed on the stud, and one having 25 teeth on the lead screw. As these gears are divisible by 5, they can be selected from the stack. Ans.

EXAMPLE 3.—A screw having $6\frac{2}{3}$ threads per inch is to be cut on a lathe geared 1 to 1, with a lead screw having eight threads per inch. If the gear stack has gears varying by six teeth from 18 to 120, what simple change gears may be used?

SOLUTION.—According to the rule, the ratio of the change gears is $\frac{8}{6\frac{2}{3}}$. Simplifying: $\frac{8}{6\frac{2}{3}}\times\frac{3}{3}=\frac{24}{20}$. Then $\frac{24}{20}\times\frac{3}{3}=\frac{72}{60}$. Hence, a gear having 72 teeth should be placed on the stud and one having 60 teeth on the lead screw. Ans.

EXAMPLE 4.—A lathe that is geared 1 to 1 has a lead screw with 6 threads per inch, and the gears in the stack vary by 5 teeth from 20 to 120. What simple change gears may be used to cut 11 threads per inch on the work?

SOLUTION.— $\frac{6}{11}\times\frac{5}{5}=\frac{30}{55}$. 30 and 55 teeth. Ans.

EXAMPLE 5.—The lead screw of a lathe geared 1 to 1 has $1\frac{3}{5}$ threads per inch, and the gear stack varies by 12 teeth from 24 to 144. Find two change gears to cut a thread of 2 threads per inch.

SOLUTION.— $\frac{1\frac{3}{5}}{2}\times\frac{5}{5}=\frac{8}{10}$, and $\frac{8}{10}\times\frac{6}{6}=\frac{48}{60}$. 48 and 60 teeth. Ans.

53. Selecting Change Gears When the Fixed Gears Have a Ratio Other Than 1 to 1.—In all problems on change gears it must be understood that the *effective* number of threads per inch on the lead screw should be used in the computations. On a lathe geared 1 to 1 the actual number of threads per inch on the lead screw and the effective number are the same, but when the lathe is geared 1 to 2 the effective number of threads per inch on the lead screw is twice the actual number; when geared 2 to 1 the effective number is one-half the lead-screw number.

EXAMPLE 1.—A lathe geared 1 to 2 has a lead screw of 6 threads per inch, and a gear stack varying by 6 teeth from 18 to 120. What two change gears may be used to cut a screw of 5 threads per inch?

SOLUTION.—The *effective* number of threads per inch on the lead screw is $6\times2=12$, and, according to the rule of Art. 51 the fraction is $\frac{12}{5}$. Then $\frac{12}{5}\times\frac{6}{6}=\frac{72}{30}$, indicating that a gear having 72 teeth placed on the stud and a gear having 30 teeth placed on the lead screw would cut the required thread. Ans.

EXAMPLE 2.—A lathe geared 2 to 1 has a lead screw of 8 threads per inch and a gear-stack varying by 5 teeth from 20 to 120. Which two change gears could be used to cut 10 threads per inch on the work?

SOLUTION.—The effective number of threads per inch on the lead screw is $8\div2=4$; according to the rule of Art. 51, the fraction is $\frac{4}{10}$. Then $\frac{4}{10}\times\frac{5}{5}=\frac{20}{50}$. Hence, a gear having 20 teeth could be placed on the stud and one having 50 teeth on the lead screw. Ans.

EXAMPLE 3.—Find two change gears that will cut a screw of $4\frac{1}{2}$ threads per inch on a lathe geared 1 to 2 with a gear-stack varying by 6 teeth from 24 to 120 and a lead screw having 5 threads per inch.

SOLUTION.— $\frac{5\times2}{4\frac{1}{2}}=\frac{10}{4\frac{1}{2}}=\frac{20}{9}$, and $\frac{20}{9}\times\frac{6}{6}=\frac{120}{54}$. 120 and 54 teeth. Ans.

EXAMPLE 4.—A lathe geared 2 to 1 has a lead screw of 8 threads per inch and a gear-stack ranging from 18 to 120 teeth, varying by 6 teeth. What two change gears may be used to cut a screw having 20 threads per inch?

SOLUTION.— $\frac{8 \div 2}{20} = \frac{4}{20}$, and $\frac{4}{20} \times \frac{6}{6} = \frac{24}{120}$. 24 and 120 teeth. Ans.

54. Calculating Change Gears When Lead of Thread is Given.—When the lead of the thread is given, that is, the advance of the thread in inches, instead of the number of threads per inch, it is necessary to change the lead to threads per inch before applying the rule. Thus, if the lead of the required thread is $\frac{3}{4}$ inch, the number of threads per inch is the reciprocal of this measurement, or $1 \div \frac{3}{4} = \frac{4}{3}$ threads. Then this number is used in the denominator of the change gear fraction.

EXAMPLE.—What pair of change gears may be used to cut a thread of $\frac{3}{16}$-inch lead on a lathe geared 1 to 1 with a lead screw having 4 threads per inch, and a gear-stack varying by 5 teeth from 20 to 100 teeth?

SOLUTION.—The number of threads per inch to be cut $= 1 \div \frac{3}{16} = \frac{16}{3}$. Ratio of change gears $= \frac{4}{\frac{16}{3}} = \frac{12}{16}$, and $\frac{12}{16} \times \frac{5}{5} = \frac{60}{80}$, which is one pair of gears that will cut the required thread.

55. Calculating Compound Change Gears.—While a simple-geared lathe has a considerable range in the number of different threads it can cut, it is unsuitable for cutting threads of large or small pitch. Thus, for cutting a thread having a pitch of $1\frac{1}{4}$ inches, it is usually necessary to use two pairs of change gears, called *compound gearing;* because otherwise an extra large number of change gears would be required in the stack, and some of the gears would have to be extra large. The same condition applies in cutting a small pitch, such as $\frac{1}{32}$ inch or less. A greater range of pitches can be cut with four change gears than with the two used in single gearing. Also the gear train runs better when the gears are more nearly of same size than in using a combination of very large gears with very small ones. Compound gears fill the space and do not require the use of an idler.

The arrangement of compound gearing is shown in Fig. 43. The two pairs of change gears are $\frac{e}{k}$ and $\frac{f}{g}$, giving a change of speed between *e* and *k* and another between *f* and *g*. The stud supporting the gears *f* and *k* is held in a slot in the arm *m* that may be adjusted so that gear *f* will mesh with gear *g*, and gear *k* will mesh with the gear *e*, and then be held by the clamp bolt *n*.

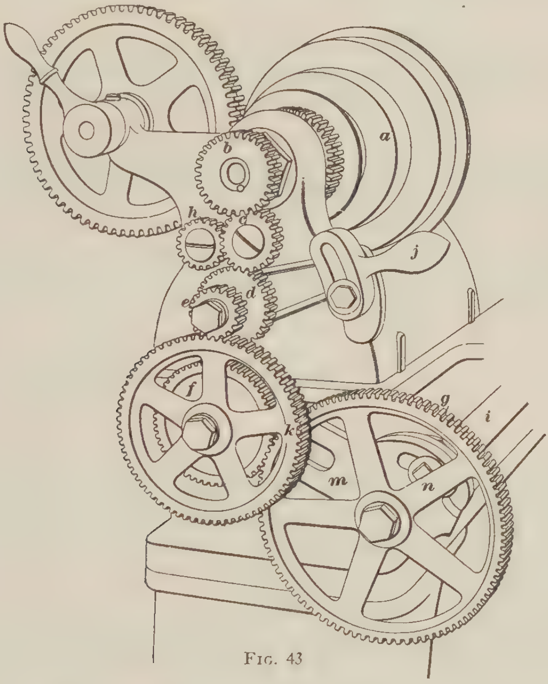


FIG. 43

Rule.—*Form a fraction whose numerator is the number of threads per inch on the lead screw, and whose denominator is the number of threads per inch to be cut; then separate this fraction into two other fractions whose product is equal to the first fraction, and then multiply the numerator and denominator of each of these latter fractions by some number that will, if possible, give the numbers of teeth on the gears in the stack. The numerators thus found will be the sizes of the drivers e and f, Fig. 43, and the denominators will be the driven gears k and g.*

It does not make any difference, so far as the motion of the lead screw is concerned, which one of the drivers is placed on the stud e, or which one of the followers is placed on the lead screw.

56. Examples of Compound Change-Gear Calculations. The following examples and solutions illustrate the application of the rule in Art. 55:

Example 1.—It is desired to cut 1 thread per inch on a lathe having a lead screw with 6 threads per inch. If the gear-stack varies by 5 teeth from 20 to 100 and the lathe is geared 1 to 1, what four change gears may be used?

Solution.—By application of the rule, $\frac{6}{1}=\frac{2}{1}\times\frac{3}{1}$. Then, $\frac{2}{1}\times\frac{25}{25}=\frac{50}{25}$, and $\frac{3}{1}\times\frac{20}{20}=\frac{60}{20}$; as there are gears of 50, 25, 60, and 20 teeth in the stack, these four gears can be selected. Ans.

Example 2.—A lathe geared 1 to 1 has a lead screw with 6 threads per inch and a gear-stack varying by 6 teeth from 18 to 120. What change gears must be used to cut $3\frac{1}{4}$ threads per inch, if compound gearing is employed?

Solution.—By application of the rule, $\frac{6}{3\frac{1}{4}}=\frac{6}{\frac{13}{4}}=\frac{6}{1}\times\frac{4}{13}=\frac{24}{13}=\frac{12}{13}\times\frac{2}{1}$. Then, $\frac{12}{13}\times\frac{6}{6}=\frac{72}{78}$, and $\frac{2}{1}\times\frac{24}{24}=\frac{48}{24}$. The gears having 72 and 48 teeth, being the drivers, would be placed at e and f, Fig. 43; and the gears having 78 and 24 teeth, being the followers, would be placed at k and g. Ans.

Example 3.—If a lathe geared 1 to 1 has a lead screw with 6 threads per inch and a gear-stack varying by 4 teeth, what two sets of change gears may be used to cut 48 threads per inch?

Solution.—By application of the rule, $\frac{6}{48}=\frac{6}{12}\times\frac{1}{4}$, or $\frac{2}{6}\times\frac{3}{8}$. Then $\frac{2}{6}\times\frac{10}{10}=\frac{20}{60}$, and $\frac{3}{8}\times\frac{12}{12}\times\frac{36}{96}$. Thus, gears having 20, 60, 36, and 96 teeth may be used to cut the desired thread. Ans.

Example 4.—If a lathe geared 1 to 1 having a lead screw of $\frac{1}{4}$ inch pitch is required to cut a screw with 14.083 threads per inch, what two pairs of gears will be required?

Solution.—The number of threads per inch on the lead screw is $1\div\frac{1}{4}=4$. By application of the rule, $\frac{4}{14.083}$ is the fraction giving the ratio of the gears. It is necessary to multiply the denominator by some number that will make the decimal a whole number. Multiplying by 12 gives $\frac{4}{14.083}\times\frac{12}{12}$

$=\frac{48}{168.996}$. For all practical purposes 168.996 may be used as 169, and with this change the fraction becomes $\frac{48}{169}=\frac{6\times 8}{13\times 13}$, and multiplying both terms of each factor by 5 gives $\frac{30}{65}\times\frac{40}{65}$, which are the two pairs of gears required. As it is very unusual to find two gears of 65 teeth in a stack, it will be necessary either to make one or to borrow one from a similar lathe. Ans.

EXAMPLE 5.—A lathe geared 1 to 2 has a gear-stack ranging from 18 to 120, varying by 6 teeth, and the lead screw has 5 threads per inch; what compound gears may be used to cut 25 threads per inch?

SOLUTION.—Apply the rule. Since the effective number of threads per inch on the lead screw is $5\times 2=10$, the change-gear ratio becomes $\frac{10}{25}=\frac{2}{5}\times\frac{5}{5}$. Then, $\frac{2}{5}\times\frac{12}{12}=\frac{24}{60}$ for one pair of gears, and for $\frac{5}{5}$ any pair of equal gears may be used. If equal gears are not available the fraction $\frac{10}{25}$ can be factored in a way that will make no two gears alike. This is done by first multiplying both terms of the fraction by some number, such as the number of teeth the gears vary in the stack, and then factoring the resulting fraction. Thus, in this problem the variation in gear sizes is 6 teeth. Then, $\frac{10}{25}\times\frac{6}{6}=\frac{60}{150}=\frac{12}{15}\times\frac{5}{10}$; $\frac{12}{15}\times\frac{6}{6}=\frac{72}{90}$, and $\frac{5}{10}\times\frac{6}{6}=\frac{30}{60}$. Therefore, the drivers may have 72 and 30 teeth, and the followers 90 and 60 teeth. Ans.

EXAMPLE 6.—A lathe geared 3 to 1 has a lead screw with 5 threads per inch, a gear-stack ranging from 20 to 100 with a variation of 5 teeth. What two pairs of gears may be used to cut $7\frac{1}{3}$ threads per inch?

SOLUTION.—The effective number of threads on the lead screw is $5\div 3=\frac{5}{3}$. According to the rule, the fraction becomes $\frac{\frac{5}{3}}{7\frac{1}{3}}$ or simplified: $\frac{\frac{5}{3}}{7\frac{1}{3}}=\frac{5}{3}\times\frac{3}{22}=\frac{15}{66}=\frac{5}{22}$. Then $\frac{5}{22}=\frac{5}{11}\times\frac{1}{2}$. But, $\frac{5}{11}\times\frac{5}{5}=\frac{25}{55}$ and $\frac{1}{2}\times\frac{50}{50}=\frac{50}{100}$. Hence the driving gears may have 25 and 50 teeth, and the followers 55 and 100 teeth. Ans.

EXAMPLE 7.—It is desired to cut $1\frac{3}{4}$ threads per inch on a lathe having a lead screw with 5 threads per inch. If the gear-stack varies by 5 teeth from 20 to 100 and the lathe is geared 1 to 1, what four change gears may be used?

SOLUTION.— $\frac{5}{1\frac{3}{4}}\times\frac{4}{4}=\frac{20}{7}=\frac{4}{1}\times\frac{5}{7}$; $\frac{4}{1}\times\frac{20}{20}=\frac{80}{20}$, and $\frac{5}{7}\times\frac{5}{5}=\frac{25}{35}$. 25, 80, 35, and 20 teeth. Ans.

EXAMPLE 8.—A lathe geared 1 to 2 has a gear-stack ranging from 18 to 120, varying by 6 teeth, and the lead screw has 5 threads per inch. What

compound change gears may be used to cut a screw having 25 threads per inch?

SOLUTION.— $\frac{5\times 2}{25}=\frac{10}{25}=\frac{1}{5}\times\frac{10}{5}$; $\frac{1}{5}\times\frac{18}{18}=\frac{18}{90}$, and $\frac{10}{5}\times\frac{12}{12}=\frac{120}{60}$. 18, 120, 90, and 60 teeth. Ans.

57. Calculating Change Gears for Cutting Metric Threads. It is often necessary to cut metric threads—that is, threads having the metric system of measurements—on a lathe having a lead screw made to inch units, or to cut threads per inch on a lathe having a metric lead screw. The change gears required may be found by the rules already given; but in order to apply these rules, it is necessary first to change the metric threads into the corresponding threads per inch. A meter is 39.37 inches, and a millimeter is .03937 inch; hence, millimeters may be changed to inches by multiplying by .03937 and inches to millimeters by dividing by .03937. The following example and solution will show the method of procedure to be used:

EXAMPLE.—It is desired to cut a metric thread having a pitch of 2 millimeters on a lathe that has a lead screw with 8 threads per inch. Find the change gears required, if the lathe is geared 1 to 1 and the gear-stack ranges by 5 teeth from 20 to 100.

SOLUTION.—A pitch of 2 mm. is the same as $2\times .03937=.07874$ in. The number of threads per inch to be cut is therefore $1\div .07874=12.7$. As the lead screw has 8 threads per inch, according to the rule of Art. **51**, the fraction is $\frac{8}{12.7}=\frac{80}{127}$. This fraction cannot be multiplied by any whole number that will give gears available in the stack, and being already reduced to its lowest terms the 80-tooth gear and the 127-tooth gear may be used to cut the required thread. There is an 80-tooth gear in the gear-stack, and if a 127-tooth gear is not on hand, it must be made. The two gears therefore contain 80 and 127 teeth. The 80-tooth gear goes on the stud and the 127-tooth gear on the lead screw. Ans.

58. Translating Gear.—The 127-tooth gear, found in Art. **57**, is known as a *translating gear*. It generally is used in cutting metric threads on a lathe having a lead screw in inch units, because 127 is the smallest whole number of millimeters that is nearest equal to a whole number of inches; for $127\times .03937=4.99999$, which is practically 5.

Compound gearing may be used instead of simple gearing, if desired. For instance, in the example just given, the fraction is $\frac{80}{127}$, which, when factored, becomes $\frac{80}{127}=\frac{40\times2}{127\times1}=\frac{40}{127}\times\frac{2}{1}$. Then one pair of gears will have 40 and 127 teeth. For the other pair, $\frac{2\times25}{1\times25}=\frac{50}{25}$, or gears of 50 and 25 teeth may be used.

59. Selecting Gears for Cutting Metric Threads.—A simple rule for selecting gears in cutting threads involving metric measurements is as follows:

Rule.—

$$\textit{Change-Gear Fraction}=\frac{5}{127}\times\frac{\textit{Pitch of thread in millimeters}}{\textit{Pitch of lead screw in inches}}.$$

EXAMPLE.—Find the change gears required to cut a thread with a pitch of 5 millimeters, the lead screw having a pitch of ½, or .5, inch.

SOLUTION.—By application of the rule,

$$\frac{5}{127}\times\frac{5}{.5}=\frac{50}{127}=\frac{25}{127}\times\frac{2}{1}=\frac{25}{127}\times\frac{60}{30},\text{ or }\frac{25}{127}\times\frac{80}{40}.\quad\text{Ans.}$$

A lead screw having 5 threads per inch practically makes a metric lathe. Thus, suppose the case where a pitch of 1 millimeter is to be cut. Then $\frac{5}{127}\times\frac{1}{\frac{1}{5}}=\frac{25}{127}$, which is the change-gear fraction. For a pitch other than 1 millimeter, multiply $\frac{25}{127}$ by the given pitch. Thus, for a pitch of 3 millimeters, the change fraction is $\frac{25}{127}\times3=\frac{75}{127}$; for a pitch of 4 millimeters it is $\frac{25}{127}\times4=\frac{100}{127}$; etc. In other words, $\frac{25}{127}$ becomes *the lathe constant* when the lead screw has 5 threads per inch. Also, a gear of 63 teeth may be used instead of the one of 127 teeth; for there are 25.4 millimeters in 1 inch and to cut a 1-millimeter pitch with a lead screw having 1 thread per inch, the lathe constant is $\frac{1}{25.4}=\frac{63}{1,600}$, approximately.

Then, to cut a pitch of 7 millimeters with a 5-pitch lead screw, for example, the change gears will be $\frac{63}{1600}\times\frac{5}{1}\times\frac{7}{1}=\frac{63}{80}\times\frac{7}{4}$ $=\frac{63}{80}\times\frac{70}{40}$.

60. Cutting Metric Threads Without Translating Gear. It is sometimes possible to cut a metric thread without the use of a translating gear, because the fraction $\frac{63}{800}$ can be factored, or split up, into $\frac{9\times 7}{10\times 80}$. This fraction is then multiplied by the pitch of the thread to be cut and the factors are treated as in compound change gearing. Thus, for 5 millimeters, the change-gear fraction is $\frac{9\times 7\times 5}{10\times 80}=\frac{9}{10}\times\frac{35}{80}=\frac{90}{100}\times\frac{35}{80}$, and these change gears may be used.

Another lathe constant that is sometimes used to cut approximate metric threads is $\frac{4\frac{1}{4}}{108}$. Then, for any pitch, such as 4 millimeters, the change-gear fraction is $\frac{4\frac{1}{4}}{108}\times 4=\frac{17}{108}=\frac{17}{18}$ $\times\frac{1}{6}$, and $\frac{17}{18}\times\frac{6}{6}=\frac{102}{108}$, and $\frac{1}{6}\times\frac{16}{16}=\frac{16}{96}$.

61. Cutting Threads in Inch Units on Lathe Having Metric Lead Screw.—If a thread having its pitch in inch units is to be cut on a lathe having a metric lead screw, the change-gear fraction is as follows:

$$\frac{127}{5\times \text{lead-screw pitch in millimeters}\times\text{No. threads per in.}}$$

EXAMPLE.—A lathe having a lead screw of 6 millimeters pitch is to be used to cut 8 threads per inch; what change gears are needed?

SOLUTION.—Apply the rule. $\frac{127}{5\times 6\times 8}=\frac{127}{40}\times\frac{1}{6}=\frac{127}{40}\times\frac{16}{96}$, or $\frac{127}{80}\times\frac{20}{60}$, etc. Ans.

62. Arrangement of Gears for Cutting Metric Threads. Most manufacturers furnish the 127-tooth gear as part of the standard equipment on their lathes. In cutting metric threads on lathes having a lead screw made to inch units, the 127-

tooth gear is placed at *a*, Fig. 44 (*a*), to mesh with the stud gear *b*. The gear *c* on the idler stud with the 127-tooth gear is usually also furnished as standard equipment to simplify the selection of the change gears. On lathes with 5 and 10 threads per inch on the lead screw, and on those having 5 and 10 millimeter lead screws, the gear *c* has 125 teeth. On lathes with 2, 3, and 4 threads per inch on the lead screw *e*, and

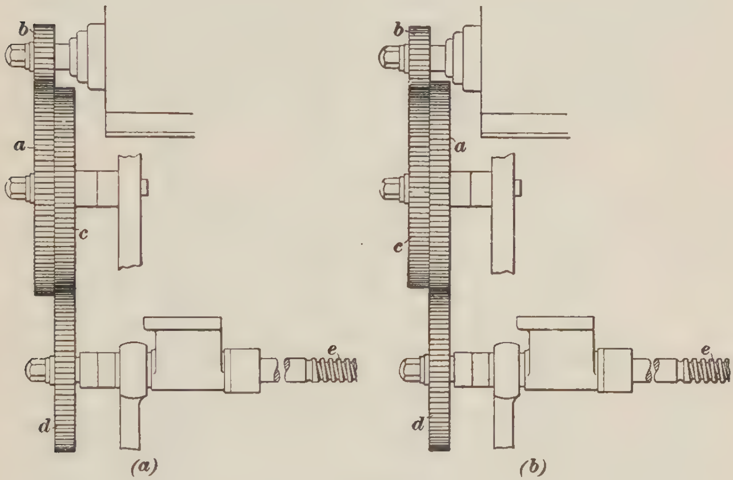


FIG. 44

those with 6, 8, and 12 millimeter screws, the gear *c* has 120 teeth.

When it is desired to cut a certain number of threads per inch on a lathe with a metric screw the arrangement is reversed and the gears *a* and *c* are interchanged, as shown in (*b*).

EXAMPLE 1.—Required to cut a thread of 8 millimeters pitch on a lathe that has a lead screw with 4 threads per inch. If the lathe is geared 1 to 1 what gears may be used?

SOLUTION.—Applying the rule in Art. **59**, the change-gear fraction $=\frac{5}{127}\times\frac{8}{.25}=\frac{40}{127}\times\frac{4}{1}=\frac{40}{127}\times\frac{120}{30}$. The arrangement of gears that would cut the required thread may be as follows: The 40-tooth gear may be placed at *b*, Fig. 44 (*a*), the 127-tooth gear at *a*, the 120-tooth gear at *c*, and the 30-tooth gear at *d*. Ans.

TABLE X

SCREW THREAD PITCHES

English Pitches			Metric Pitches		
Threads per Inch	Pitch		Pitch		Threads per Inch
	Inches	mm.	mm.	Inches	
4	0.2500	6.350	8.0	0.3150	3.2
$4\frac{1}{2}$	.2222	5.644	7.5	.2953	3.4
5	.2000	5.080	7.0	.2756	3.6
6	.1667	4.233	6.5	.2559	3.9
7	.1434	3.629	6.0	.2362	4.2
$7\frac{1}{2}$	.1333	3.387	5.5	.2165	4.6
8	.1250	3.175	5.0	.1968	5.1
9	.1111	2.822	4.5	.1772	5.6
10	.1000	2.540	4.0	.1575	6.4
11	.0909	2.309	3.5	.1378	7.3
$11\frac{1}{2}$	.0870	2.209	3.0	.1181	8.5
12	.0833	2.117	2.5	.0984	10.2
13	.0769	1.954	2.0	.0787	12.7
14	.0714	1.814	1.75	.0689	14.5
16	.0625	1.588	1.50	.0591	16.9
18	.0556	1.411	1.25	.0492	20.3
20	.0500	1.270	1.00	.0394	25.4
24	.0417	1.058	.90	.0354	28.2
27	.0370	.941	.75	.0295	33.9
28	.0357	.907	.60	.0236	42.3
32	.0312	.794	.45	.0177	56.4
36	.0278	.706	.42	.0165	60.5
40	.0250	.635	.39	.0154	65.1
44	.0227	.577	.36	.0142	70.6
48	.0208	.529	.33	.0130	77.
56	.0179	.454	.30	.0118	85.
64	.0156	.397	.27	.0106	94.
72	.0139	.353	.24	.0094	106.
80	.0125	.318	.21	.0083	121.
			.19	.0075	134.
			.17	.0067	149.
			.15	.0059	169.
			.13	.0051	195.
			.11	.0043	231.

EXAMPLE 2.—What gears may be used to cut a screw of 6 threads per inch on a lathe geared 1 to 1 having a 10 mm. lead screw?

SOLUTION.—Applying the rule in Art. **61**, the change-gear fraction is $\frac{127}{5\times10\times6}=\frac{1}{5}\times\frac{127}{60}=\frac{25}{125}\times\frac{127}{60}$. The 25-tooth gear would be placed at *b*, Fig. 44 (*b*), the 125-tooth gear at *c*, the 127-tooth gear at *a*, and the 60-tooth gear at *d*. Ans.

63. Comparison of Metric and English Screw Pitches. For comparison of screw-thread pitches for both the English and metric systems, Table X will be found useful for finding the nearest equivalent of one system in terms of the other. Millimeters are sometimes abbreviated mm.

CUTTING EXTERNAL THREADS

64. Locating the Work.—The piece to be threaded should have the center holes well cleaned and oiled. A dog is clamped securely on the end opposite the one to be threaded and the work is adjusted to turn freely between the centers. The part to be threaded is turned to a uniform diameter. The thread tool is set square to and with its top at the same height as the axis of the work and clamped securely. The change gears are placed in position, and clamped so that nothing can slip while the thread is being cut. The feed should be set to move the carriage toward the headstock to cut a right-hand thread, and in the opposite direction to cut a left-hand thread. The tumbling gear is used to get the required direction of feed.

65. Correct Height of Threading Tool.—The top face of the threading tool should be set level with the center of the work. If the thread tool is set too high or too low, the threads will not be cut deep enough, their angle will be too great, and their sides, instead of being straight, will be curved hollow. These three defects on an enlarged thread are shown at *a* in Fig. 45. In this illustration the correct thread is cut at *a*, and the shallow thread with hollow sides cut by the same tool as *a*, but when set too high, is shown at *b*. To allow for spring, set slightly above the center.

66. Drawing of Thread Cut With Tool Set Above Centers. Suppose that a threading tool having the correct form, Fig. 45 (*b*), to cut a 60-degree sharp **V** thread be set with its top face on the line *a b* level with the center *c* of the screw. Then a thread cut to any required depth, as *a b*, will have an angle of 60 degrees, as shown by its top view *b c d* laid off on the

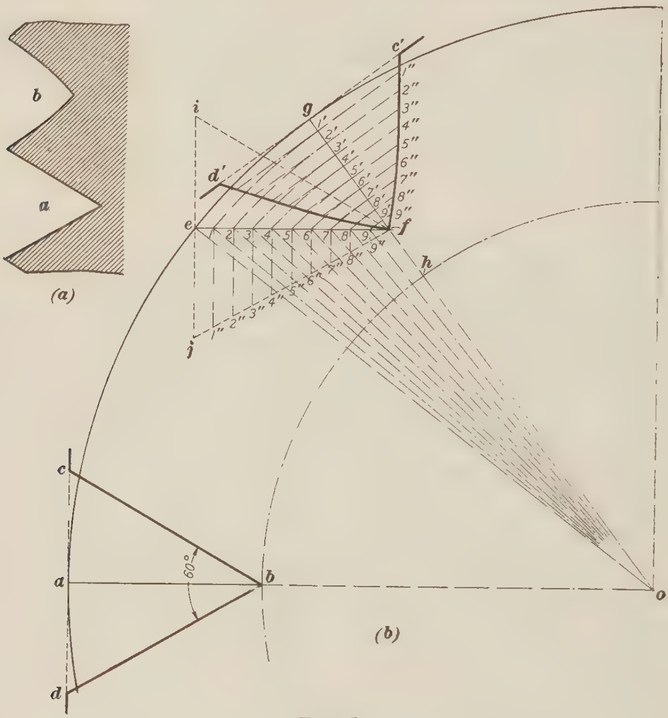


Fig. 45

center line *a b*. The pitch of the thread is *c d*, which is equal to the side *b c* or *b d* of the thread. Then suppose that instead of being set at *a b*, this same tool is set above the center *o* at some point *e*, and that the cut is made to a depth *e f* = *a b*. The actual depth of the thread cut at this location is *f g*, because the thread depth must always be measured on a radial line, which is a line *g f h o* drawn to the center of the threaded piece. It will be seen that the actual height *f g* is

less than the required height $a\,b$ by a distance $f\,h$, so that the thread is not deep enough.

To show the second and third defects, lay off the outline of the thread to a radial depth $f\,g$ and having a pitch $c'\,d' = c\,d$. For convenience, the form of the tool is laid off at $j\,f\,i$. Divide the line $e\,f = a\,b$ into a number of equal parts, as 10. Then from each of the points 1, 2, 3, etc. draw a circular arc 1–1′, 2–2′, 3–3′, etc. using each radius from the center o. These arcs will divide the depth $f\,g$ of the short thread into the same number of equal parts as were made in the correct height $e\,f = a\,b$. Then through each point 1′, 2′, 3′, etc. draw a line parallel to the pitch line $c'\,d'$, and on each of these lines lay off on each side of the center line $f\,g$ a distance 1′–1″, 2′–2″, 3′–3″, etc. equal to the actual widths cut by the tool, such as 1–1″, 2–2″, 3–3″, etc. Finally, the heavy lines $f\,c'$ and $f\,d'$ drawn through the ends of these lines will correspond to the form of the thread as actually cut. An inspection of this form shows that the angle $d'\,f\,c'$ at the root of the thread is larger than 60 degrees, and that the sides of the thread are curved hollow instead of being straight lines between f and d' and between f and c'.

67. Sidewise Spring of Threading Tool.—When the threading tool starts into the cut, there is a tendency for the tool to spring to one side, away from the work, before both sides are supported in the cut, and for the first half revolution the cutting is done only by one edge. The tool will thus be sprung away from the cut. After the work has made a complete revolution, the pressures on the two sides of the tool balance each other and the tendency to spring sidewise is gone. This spring of the tool will make the first thread on the work slightly thicker than the others, so that in testing the work the nut will be found to be tight on the end, and after it has passed over this thick thread, the fit will be loose. This condition may be avoided by taking two or three light cuts over the first thread and cutting it a little deeper than the following threads, when cutting **V** threads. Special care should be taken to have the tool extra sharp and with plenty

of clearance on the leading side, that is, the side toward which it is moving.

68. Breakage of Thread Tools.—Sometimes the point of the thread tool will be chipped off from the right side, as shown in Fig. 46. This kind of break is usually caused by the slipping of the dog. The breaking strain was toward the right in the direction of the arrow. When the tool takes a heavy cut and the dog slips, the work will stop revolving while the lathe and feed continue. When the feed continues and the tool point is in the thread, the tool must either slip or break. Sometimes a tool will break by chipping off the top face, as indicated in Fig. 47. Such a break indicates

FIG. 46

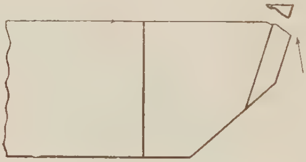


FIG. 47

that the lathe was reversed and the work was running backwards before the tool was withdrawn from the cut. If the thread tool is too hard, the point will crumble; if too heavy a cut is taken, the point will be either broken downwards or burned off.

69. Setting Threading Tool.—Threading tools should be clamped in the tool post at such an angle to cylindrical work that the cutting edges NS and GK of the tool, Fig. 48, will make equal angles with the work. This is accomplished by using a center gauge, as shown. The back of the gauge lies flat against the work, and the point of the tool is so moved that it just fits the notch in the front of the gauge. As the point of the tool is ground to an angle of 60 degrees and the sides of the threads to be cut make an angle of 60 degrees, the angle between one of the faces of the tool and the work

will be an angle of 60 degrees. It will therefore be found more convenient on some kinds of work to hold the gauge as shown in Fig. 49, with one angular edge against the work, and to set the tool to the other angular edge. When one edge of the tool is properly set, the other edge will be at the correct angle, provided the tool is correctly ground.

70. Grinding Threading Tool.—The threading tool may be ground by the same method used in grinding ordinary lathe tools, the gauge being used to test the angle of the point. Whenever possible, it is better to grind the tool in

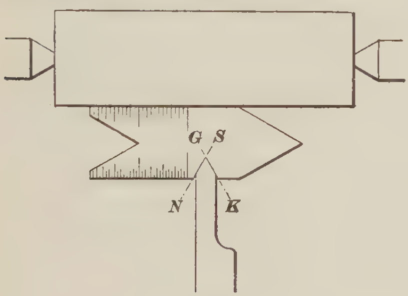


FIG. 48

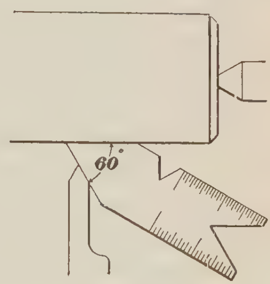


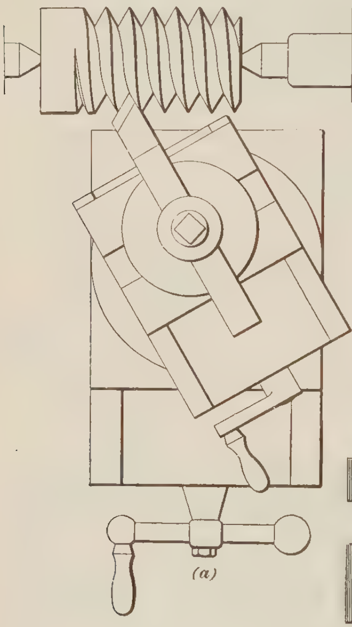
FIG. 49

a machine especially designed for the purpose. With these machines, it is possible to grind more accurate angles and truer faces than by hand.

71. Use of Threading Tools With Top Rake.—The ordinary threading tool that cuts with its two edges cannot have any top rake or keenness. A thread may be cut with a tool having top rake by using the compound rest set at an angle of 60 degrees with the center line of the work, as shown in Fig. 50 (*a*), and a tool shown in (*b*). The tool is ground so that the broad cutting edge *C D* makes an angle of 60 degrees with the side of the tool, and slope or top side rake is given to the top face. When the cut is taken, the tool is fed into the work by the compound rest. As the rest is set at an angle of 60 degrees, the blank side *A B* of the tool will just slide by the side of one thread while all the cutting is done

with the keen edge CD of the tool. Large threads are cut in this way.

72. Resetting Threading Tool.—When the threading tool has been removed, it may be reset as follows: Adjust the tool in the tool post to fit the gauge, Fig. 48, the same as before the thread was started. Turn the spindle forwards and note if the tool point comes opposite the cut in the work. If not, drop the intermediate gear *c*, Fig. 39, away from the gear *b* on the spindle. Turn the spindle forwards until the tool comes exactly opposite the notch in the work. Bring the tumbler gear in mesh with the spindle gear, which will throw in the feed, and proceed to cut the thread, as before. The lathe



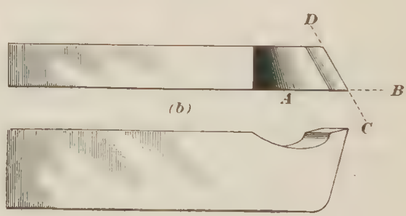


Fig. 50

must always be turned forwards, so as to take up the slack or backlash in the gears and the lead screw. The backlash can be noted at the time the lathe is reversed, when it will be seen that the work may make a part of a turn before the tool will start to feed back. The tool will then drag behind, and if brought up when the work is running backwards, the tool would not fit in the notch as it did when the lathe was running forwards. If the lathe has a compound rest it should be set around about 30 degrees before setting the thread tool square

with the axis of the work. If the thread tool does not enter the thread cut in the work as the work turns for cutting, the tool can be advanced sidewise by use of the compound rest, so that it fits perfectly in the cut already made.

73. Opening Lead-Screw Nut.—If short threads are being cut, it is usually best to leave the split feed-nut closed and run the tool back to the starting point for each new cut. The thread is cut by running the lathe backwards and forwards the required number of times to cut to the required depth. If the screws to be cut are long, the split nut should be opened and the carriage returned by hand.

If the pitch of the thread to be cut is not a multiple of the pitch of the lead screw it is best to proceed as follows: First the carriage is run back so that the tool is an inch or more away from the thread and then run forwards enough to take up the backlash. A mark is made on the lathe bed at the point where the carriage starts. Another mark is placed on the large spindle gear, with a corresponding mark on the headstock casting. A third mark is made on the lead-screw gear and frame. When the end of the cut is reached, open the nut and move the carriage back to the starting mark. Then watch for the marks on the spindle gear and the lead-screw gear to coincide with their respective marks on the frame. When all three marks register as in starting the first cut, close the nut.

If the pitch of the thread being cut is a multiple of the lead-screw pitch, the nut may be opened, and after the carriage is returned to the starting point it may be closed anywhere and the tool will be in position to start in the cut. In this case it is possible to keep the lathe running forwards all the time by throwing out the feed and moving the tool and carriage by hand back to the starting point. This operation will save much time.

74. Thread Indicator.—The thread indicator, shown in Fig. 51, is used to show when to close the split nut on the lead screw while a thread is being cut. It consists of a worm-wheel *a* connected to a short, vertical shaft that turns

in the bracket *b* and carries a dial *c* at the upper end. The bracket is swiveled on the pin *d*, so that the indicator may be swung away from the lead screw *e* when it is not in use; or it may be removed entirely. A pointer *f* is formed on the upper end of the bracket and the split nut is thrown in when the proper graduation comes opposite this pointer.

75. Lubrication for Thread Cutting.—When threads are being cut on steel or wrought iron in a lathe, lard oil should be freely applied to the tool and the work. The finishing cuts

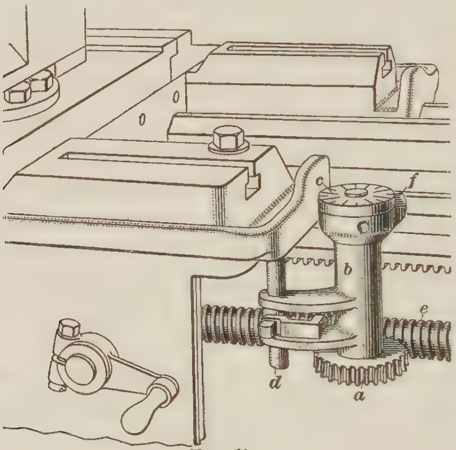


FIG. 51

should be light shaving cuts. The tool should be ground sharp and finished with an oilstone. The oil is usually applied to short threads by placing a pan of oil under the work and putting the oil on with an oil brush. If the screws are long, an oil pan is placed under the work and a drip can is so arranged that a supply of oil will follow the work above the tool. No lubricant is necessary in threading cast-iron or brass.

76. Cutting V or United States Standard Threads.—The tool is fed in until the point just touches the work as the lathe runs forwards. A light cut is traced on the work to the end of the thread, where the lathe is stopped.

After the first and very light cut is made on the work with the point of the tool, it is good practice to hold a scale against the threads and count the number to the inch to see whether the lathe is cutting correctly. If a mistake is discovered it can be rectified; if the error of pitch is not discovered until the thread is cut, there is no remedy. The tool is then drawn back by a turn or two of the cross-feed screw and the lathe reversed to run the carriage back to the starting point. The tool is fed in the required distance for another cut and run over the thread as before. These operations are repeated until the thread is cut to such a depth that it will screw into a nut or tapped hole and show a good bearing on the sides of the threads. The last, or smoothing, cuts should be very light.

77. Cutting Square Threads.—A square thread is often required to stop abruptly in the stock, so a hole *b*, Fig. 52, is drilled at the place where the thread will end, into which the tool can run and cut off the chip. To cut a square thread, the tool is first set so that it will come central with the drilled hole at the end of the cut. The lathe is stopped when the tool is within half a turn of the hole and the belt is pulled around by hand until the chip is cut off. The tool is withdrawn and the operation is repeated until the thread is cut to the required depth. The finishing tool is then carefully set square with the axis and level with the center and light cuts are taken until the correct depth is reached. Lard oil is always applied to the tool and the work when the harder metals are being cut.

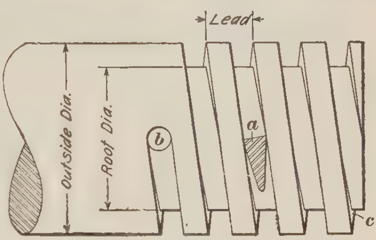


FIG. 52

78. After the thread is cut it may be found that, at the point where the tool cuts only on one side as it starts into the cut, as at *c*, Fig. 52, the thread will be thicker than where the tool cuts and is supported on both sides. This high side of the thread should be carefully filed down to the same thick-

ness as the rest of the thread, after which it should be well oiled and tried in the nut. If the thread is too tight it can be eased off by running a thin file along its side until it fits correctly.

If the thread is quite large, as four or less per inch, it is better to use narrow tools, say three-fourths of the width of the space, and then finish with a tool ground to the correct width. It is usual to make the thread-tool wide enough so that it will just crowd between the teeth of the tap used to make the nut. The fit can then be perfected with very little filing.

79. Cutting Acme and Similar Special Threads.—The cutting operations followed in roughing and finishing the Acme

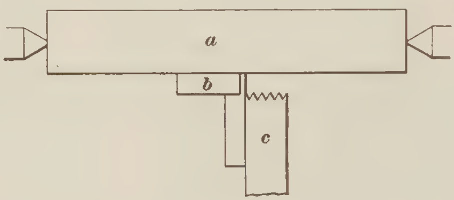


FIG. 53

thread do not differ materially from those followed in cutting a square thread. An Acme thread is best roughed out like a square thread, with a tool having a width equal to the space at the bottom. Then the compound rest is set over $14\frac{1}{2}$ degrees, first on one side and then on the other, and the two sides of the thread are finished.

80. Setting Formed Threading Tool for Whitworth Threads.—Formed threading tools are generally made so that the cutting edges are at right angles with the shank. Then they can be set in the tool post by means of a small square, as in Fig. 53, which shows the work *a*, the square *b*, and the tool *c*. Another method of setting the tool is to clamp it with its side parallel with the face plate, a pair of inside calipers being used to measure the space between the tool and the face plate to obtain the correct setting.

81. Cutting Double Threads.—When a double or other multiple thread is to be cut, two or more threads must be cut in the space that ordinarily would be required for a single thread. A double **V** thread is cut by gearing the lathe to cut the lead of the double thread, which is twice the pitch of a single thread of the same height. Proceed as in cutting a single thread until the space left between the grooves is equal to the width of the grooves, as shown in Fig. 54. The work is turned half way around so that the point of the tool will be opposite the center of the uncut part, as shown. This half turn may be made by removing the work and locating the tail of the dog in the notch of the face plate diametrically opposite the one used for the first thread.

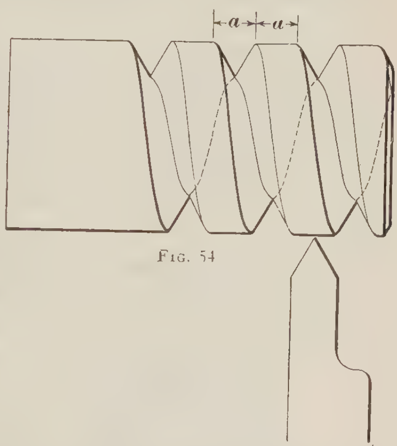


Fig. 54

82. If the face plate is not evenly slotted for multiple threading, another and better method for giving the half turn is to disconnect the feed-gears, and then turn the lathe spindle and the work half a turn. Suppose a change gear with 48 teeth is on the stud. One of its teeth that meshes with the idler, and also the tooth diametrically opposite it on the stud gear, are marked with chalk, and the mark is carried onto the idler gear, after which the two gears are disconnected by dropping the idler yoke. The spindle and work are then turned so that the stud change gear passes over half its number of teeth, or 24 teeth. The work will have made half a revolution when the second mark on the stud gear coincides with the mark on the idler gear. The gears are then brought in mesh and the second thread cut the same as the first. *If the lathe is compound-geared between the spindle and stud, the stud gear, instead of being turned half a turn, is turned a proportional part, depending on the ratio of the*

compound. If, for example, the spindle makes two turns to one of the stud, the stud gear would make a quarter-turn.

83. Cutting Triple Threads.—After the first thread is cut, the space between the grooves should be double the width of the groove. The work is turned a third of a revolution and the second thread cut; then after a turn of another third of a revolution the third thread is cut.

If the gear usually used on the stud to cut a thread with the given lead is not divisible by three it is usually possible to substitute another set having the same ratio. For example, if the thread would ordinarily be cut with a 20-tooth gear on the stud and a 60-tooth gear on the lead screw, then, in order to cut a triple thread, a 24-tooth gear may be used on the stud and a 72-tooth gear on the screw. This keeps the ratio the same and yet permits the use of a 24-tooth gear on the stud, where a shift of 8 teeth at a time for each thread can be made. A similar method is used for cutting quadruple threads.

84. Face Plate for Multiple Threading.—A convenient device for giving the face plate the required part of a revolution

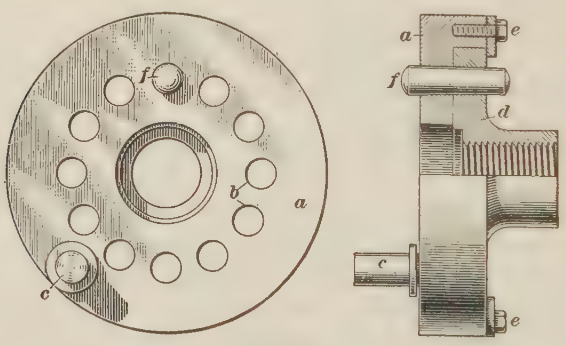
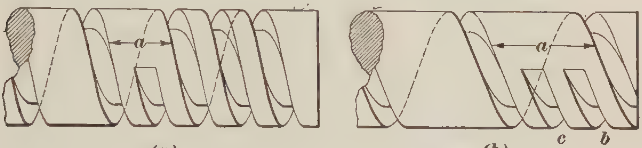


Fig. 55

for cutting multiple threads is shown in Fig. 55. It consists of a flanged circular plate *a* having any desired number of equally spaced holes *b*. The plate carries a stud *c* to engage the lathe dog, and the plate is fitted over the face plate *d* and

clamped to it by two capscrews e. To revolve the face plate with the work a definite part of one revolution, the screws e are loosened and the index pin f withdrawn. The plate a is then turned the required number of holes, and the index pin replaced and the screws e tightened again.



(a) (b)

Fig. 56

85. Cutting Multiple Square Threads.—Multiple-threaded screws are more generally cut with square threads. The work is reset, after each thread is cut, in the same way as for **V** threads; however, the blank space left, after the first groove is cut, is not the same in both cases, owing to the difference in the shape of the thread. From Fig. 56 (a) it will be seen that, after the first groove of a double thread is cut, the space a will be three times the width of the groove. Similarly, in (b) when the first groove of a triple thread has been cut, the space will be five times the width of the groove. This will allow the second and third grooves to be cut with the tool at b and c, respectively.

86. Cutting Worm Threads in the Lathe.—Worms are cut in the lathe in the same way as square threads, except that a special forming tool is required to give the thread its shape. More accurate worms are produced by milling or hobbing.

87. Cutting Left-Hand Threads.—These are cut in exactly the same way as right-hand threads except that the cut is started from the left-hand end of the work and the carriage travels toward the right while the cutting is being done. The tool may be started into the cut by feeding it in by hand gradually with each succeeding cut, or by drilling a hole large enough to allow the thread tool to be set clear to the bottom of the proposed thread. For a square thread this should be

the diameter of the space between the threads and for a **V** thread it should equal the pitch of the thread. The tool is then started from the hole when set at the depth required for each cut.

88. Graduated Dial on Cross-Feed.—The increased depth of each succeeding cut, when a screw thread is being formed, may be regulated by the attachment shown in Fig. 57. It consists of a sleeve *a* that is firmly fixed in the saddle *b* and that forms a bearing for the cross-feed screw *c*. A graduated dial *d* is placed on the outer end of the stem of the feed-screw and is made adjustable, so that its zero can be set in line with a mark on the sleeve *a* when the point of the threading tool is

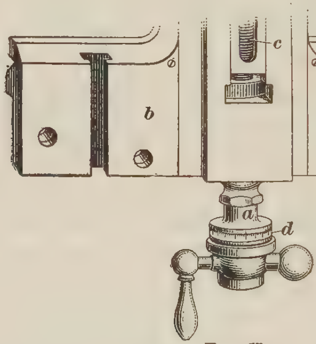


FIG. 57

just touching the work. At each succeeding cut the screw *c* is turned more, and the dial *d* shows the depth to which the tool cuts. The dial is graduated to read in sixty-fourths or in thousandths of an inch.

89. Screw Stop.—The older lathes commonly had a thread stop clamped on the cross-slide, or some similar method was used to gauge the depth of cut when threading was being done. Such a stop is arranged on the cross-slide, as shown at *b*, Fig. 58. The stop is rigidly fastened to the slide by tightening the setscrew *a*. An adjusting screw *s*, with a large shoulder and a nurled head, passes loosely through the stop and screws into the tool block *t*. When the stop is adjusted as shown, the tool and tool block can be moved away from the

work, as the screw *s* is not threaded in the stop-block *b*. When the block is moved forwards, it can move only until the head of the screw *s* comes against the stop. After the tool has

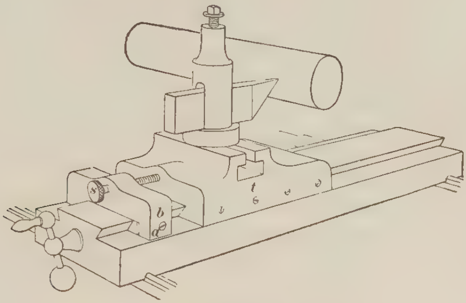


Fig. 58

passed over the work and it is desired to take a deeper cut, the stop-screw *s* is unscrewed a partial turn; the tool is thus allowed to advance slightly, according to the amount the screw is turned.

CUTTING INSIDE THREADS

90. Holding Work for Cutting Inside Thread.—When an internal thread is to be cut in the lathe, the work is held in a

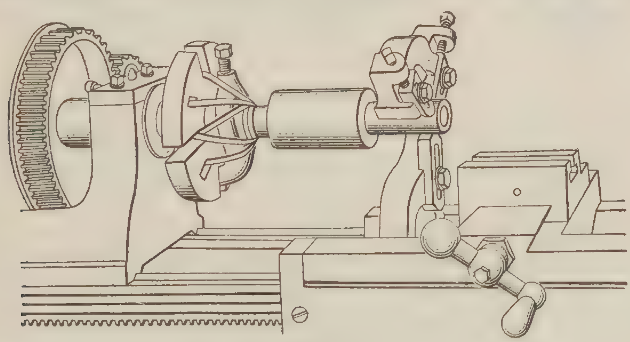


Fig. 59

chuck or on a face plate, the same as for boring. If the work is long, one end is held in the chuck or on the live center, and the outer end is supported in a steady rest while the boring and threading are being done. If the work is held on the center,

a hold-back is required. One form of hold-back is shown in Fig. 59. In it a rawhide belt lace is used. The dog is clamped on the work as usual, and the work is placed on the center, after the face plate has been unscrewed half way. The lace is then used as shown, to lash the dog to the face plate, after which the ends of the lace are securely tied. The face plate is then screwed home, which draws the lace tight and the work into position. This is safe for light work only.

91. A special hold-back dog is shown in Fig. 60. It consists of a clamp dog *a* secured to the work and has two slotted arms *b* through which studs *c* pass and enter slots or

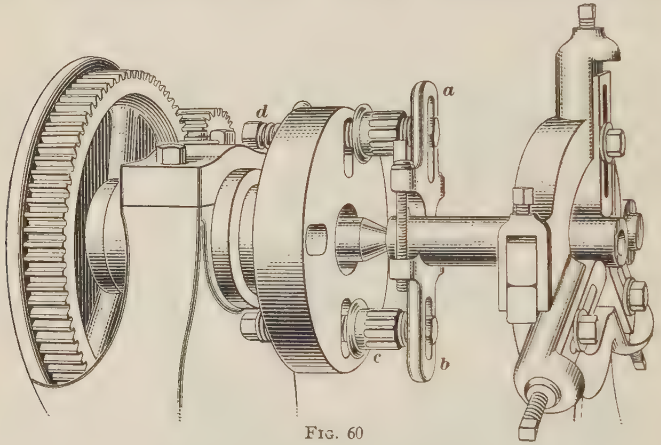


FIG. 60

holes in the face plate. Nuts *d* on the other ends of the studs are used to take up the slack and bring the work firmly against the live center.

A very good hold-back is made from a piece of hardwood 1 inch thick, of any required length and width. A large hole is bored central for the work to pass through and a hole near each end for each of two $\frac{1}{2}$- or $\frac{5}{8}$-inch bolts. The wooden hold-back is slipped on the work and the dog fastened as shown in Fig. 59. The hold-back is then brought up against the dog and the bolts are passed through it and the face plate, as shown in Fig. 60. Enough tension is put on the bolts so that the work is held back against the live center without springing.

92. Stop for Inside Thread Cutting.—In cutting inside threads, the stop shown in Fig. 58 may be used by taking the screw out of the stop and putting it in the tool block so that it comes between the tool block and the stop. For inside screw cutting, to take the tool out of the cut it is necessary to move the tool in an opposite direction from that required in outside screw cutting. The stop-screw must therefore be so adjusted that the head of the screw comes against the stop. Deeper cuts may be made by turning the screw into the tool block.

93. Setting Inside-Thread Tool.—The inside-thread tool is set by placing one of the long parallel edges of the center

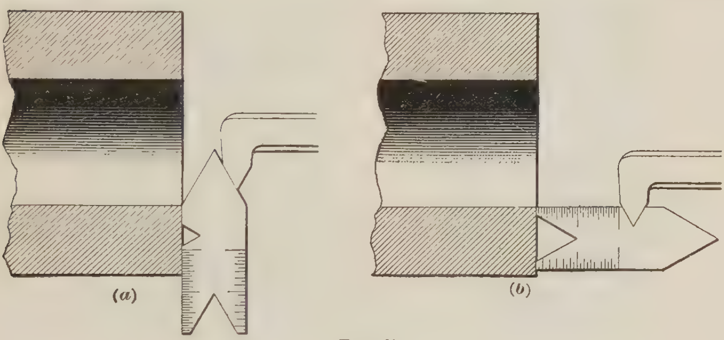


FIG. 61

gauge against the face side of the work so that the pointed end faces the thread tool that is clamped loosely in the tool post. The tool is then clamped with its front edge even with the angular edge of the gauge, as shown in Fig. 61 (*a*). It may also be set by placing the legs of the center gauge against the true-faced surface, and setting the tool to the small notch in the side of the gauge, as shown in (*b*). If the face of the work is too narrow to line up the end or edge of the gauge, a steel scale may be held across the work and the gauge held against the scale.

94. Operation of Cutting Inside Threads.—When the inside thread tool is correctly set and the change gears are in

place, the point of the tool is brought up to the surface of the hole next to the workman, and a light cut is traced through the hole. The stop or dial is set, and the tool is moved out of the cut and then backed out of the hole by reversing the lathe. If possible, a gauge is tried on the traced thread to make certain that the gearing is correct. Repeated cuts are then taken until the thread is deep enough. Lighter cuts are generally necessary in cutting an inside thread than in cutting an outside thread, because the tool is longer and will spring easier than the outside thread tool. Any spring is very objectionable, as it results in chattering, which will make the threads rough and sometimes tapered small at the inner end. If possible, it is best to finish internally threaded holes by a tap guided by a center in the dead spindle. The tap should be well oiled and run carefully through the chased hole, while a wrench is kept on the shank to prevent it from turning with the work.

ERRORS OF THREADS CUT ON ENGINE LATHE

95. Errors Due to Imperfect Lead Screw.—The chances for error in screws cut in the lathe are numerous. The chief error is the inaccuracy of pitch due to an imperfect lead screw. The best remedy for errors of this kind is to use a lead screw that is known to be perfect within a given limit. All the lathes in a shop should be tested, and all particular screw-cutting given to those having the most perfect lead screws. In cutting long screws, the work frequently becomes heated above the temperature of the lead screw. Consequently, the screw being cut will be short when cool. The remedy is to keep the work cool with plenty of oil or water.

96. Accuracy of Lead-Screw Pitch.—When screws of accurate pitch or lead are desired, or when screws are desired that will be true with the axis of the work, they can be cut with more certainty on the lathe than with dies. For ordinary threads, the ordinary lead screw is sufficiently accurate. When greater accuracy is required for such work as making taps or dies, the making of precision screws for measuring

instruments, or similar work, a lead screw that has been most carefully made and has been tested all along its length must be used.

97. Perfectly Fitted V Thread.—A **V** thread is sharp at its point and at its root, as was shown in Fig. 1. If a 1-inch thread were being cut, the thread would be complete when the groove cut by the tool just formed the sharp point of the thread. It is difficult to know just when this point is reached; therefore, the work is taken from the lathe and tested with a gauge or in the piece it is to fit. Fig. 62 represents a section through a bolt and a nut, showing how accurately the faces of the threads should fit each other. In practice it is usually

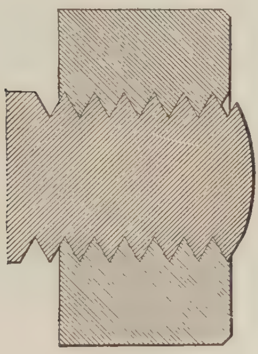


FIG. 62

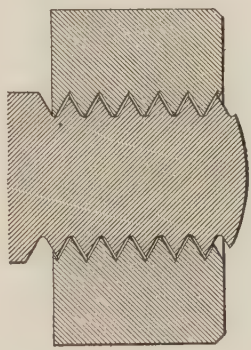


FIG. 63

better to turn the part to be threaded $\frac{1}{64}$ inch under size to be sure that the points of the thread will not bear in the threaded hole, thereby causing the workman to think that the sides of the thread are too full, and thus leading him to cut too deep and make a loose fit.

98. Effect of Using Dull Thread Tools.—A bolt threaded with a dull-pointed tool is shown in Fig. 63. The threads are rounded at the bottom because of the rounded point of the tool. When this kind of thread is tried in a perfectly threaded nut, as shown, it will not enter until the thread is cut sufficiently deep to allow its rounded root to pass in. This may so hold the work that no lost motion can be detected at first; but the

piece will soon wear loose, as there is no bearing on the sides of the threads as there should be.

99. Fitting Threads to Nuts Tapped With Dull Taps.—In the case shown in Fig. 64, the nut to be fitted has been tapped with a dull tap, which left the threads slightly rounded in the bottom. When a sharp-threaded screw of full diameter, as cut on a lathe, is tried in such a nut, it will not enter. By cutting the screw smaller, it will go in; but the fit will be as shown, the bearing being entirely on the points of the threads. In practice, when the screw thread has been cut to a sharp point and will not enter, this trouble should be looked for,

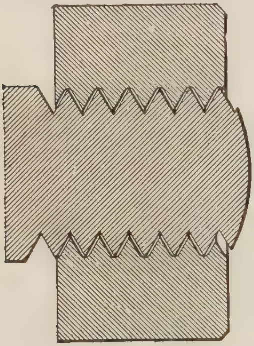


Fig. 64

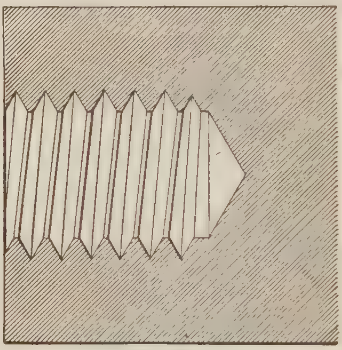


Fig. 65

and if the threads in the nut are found imperfect, the points of the screw being cut should be slightly rounded with a file. A screw thread should always fit by bearing on the sides of the threads and never on the points.

100. Advantage of Large Tap Holes.—In machine construction where holes are drilled and tapped for V threads in various parts of castings, it is customary to drill the holes slightly larger than would be necessary to cut such a full sharp thread as shown in Fig. 62. After the holes are tapped, they are more nearly of the shape shown somewhat exaggerated in section in Fig. 65, where it may be seen that the threads are not full on the points. When a bolt, threaded on a lathe, is being fitted to this kind of tapped hole, it is not so important to

keep a very sharp point on the lathe tool and to cut the thread sharp at the root.

101. Effect of Slight Difference of Pitch on Fit.—A section through a bolt and a nut having slightly different pitches is shown in Fig. 66. In fitting such a bolt, it will be found on trial that the bolt enters the nut easily, for a few turns, growing tighter as it is screwed in, with the appearance of being tapered. After more cutting on the lathe the bolt will pass through the nut, appearing to fit. When the end of the bolt is once passed through the nut, it will not fit any more closely as the nut is screwed along the bolt. When a bolt and a nut are of slightly different pitches, the effect is much more noticeable if the nut is long than if the nut is short. The real contact may be seen from Fig. 66. In this case, the thread on the bolt is of a coarser pitch than the thread on the nut, and bears only on the first and last threads of the nut.

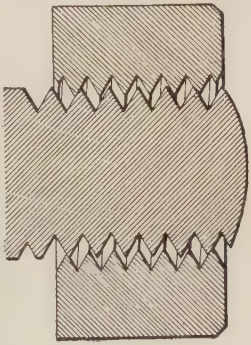


FIG. 66

102. Fitting Threads on Same Lathe.—When two threads are to be cut that must fit each other perfectly, the internal thread being long, it is desirable that they be cut on the same lathe. By its use they can be made to have the same pitch, and if there is any error in the pitch, it will be the same in both threads.

103. Replacing Work in Lathe.—If, after testing in the nut, the screw is found to be too large, it should be replaced in the lathe and a sufficient number of light cuts taken to reduce it to the desired size. The notch in the face plate used for the tail of the dog must be noticed and marked, and the dog put back in the position from which it was taken. Failure to do this will cause the point of the tool to start another thread that will destroy the one nearly completed.

THREADING TAPERS

104. Threading Tapers by Setting Over Dead Center. The general practice of cutting **V** and United States Standard threads on tapers is to set the tool square with the axis of

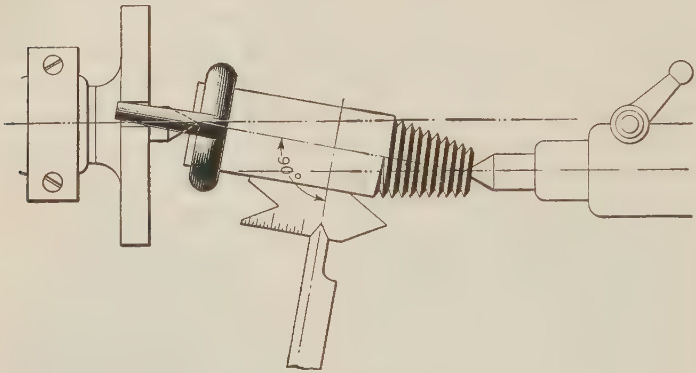


Fig. 67

the taper, as shown in Fig. 67. This setting cuts the thread with its sides making equal angles with the axis of the taper. After setting over the tail center until the taper becomes parallel with the lathe **V**'s, the center gauge may be set against the parallel part of the work and the tool adjusted to fit the notch, as shown. The threads will then fit the nut which has its threads cut square with the axis. This form of thread has the least bursting effect on the nut.

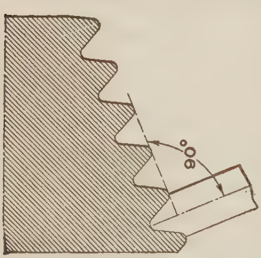


Fig. 68

105. Threading Whitworth Tapers.—The Whitworth thread on tapered work is cut by setting the tool square with the tapered surface, as shown in Fig. 68. This method permits the use of the same tools used for cutting threads on cylinders. In order to cut circular points and roots with these tools, it is necessary to set them square with the surface as shown

106. Errors in Tapered Threads Due to Setting Over Tailstock.—A true thread can not be cut by setting over the tailstock. The axis of the thread is not in line with the axis of the lathe spindle. This causes the thread to have a wave, called a *drunken thread.*

The pitch of a tapered thread cut by setting over the tail center is shorter than the true pitch. This error is illustrated in Fig. 69. Suppose the tapered piece is 2 inches long and should have 10 threads per inch, or a pitch of $\frac{1}{10}$ inch. This means that for 10 revolutions of the piece the threading tool will advance 1 inch, and to advance 2 inches, it would

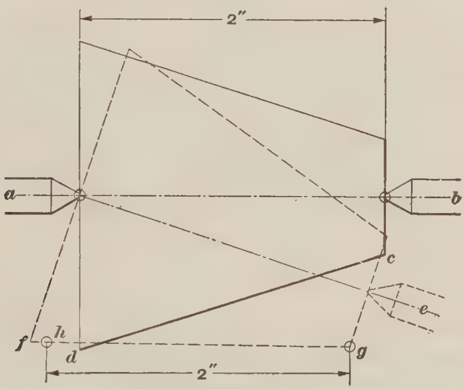


FIG. 69

require 20 revolutions, and the piece should have 20 threads. This result would be obtained when the lathe centers *a* and *b* are in line. The tool will start at *c* and, after 20 revolutions of the work, will have moved 2 inches sidewise to the end *d*, the carriage moving parallel to the lathe center line *a b*.

107. When the tailstock center is set over, as at *e*, the tool will move parallel to the surface *f g* of the taper. If the cut starts at the corner *g*, 20 revolutions will move the tool 2 inches to the point *h*. It will be seen that a part *h f* remains unthreaded. The part *h f* is equal in length to the difference between the slope *f g* of the taper and the 2-inch axis. Therefore, more than 20 turns are necessary to thread the taper, and hence the pitch is shortened.

The offset of the tail center is also liable to cause an error in tapered threads because of the unusual wear of both the tail center and the work centers. This wear makes it necessary to bring the lathe centers closer together and thus changes the taper. The amount of the error depends upon the length of the work and the angle of the taper.

108. Threading With Taper Attachment.—When the taper attachment is used for threading, the tool is set by placing the center gauge against the cylindrical part, as in Fig. 70. The gauge could be set in like manner against the tailstock

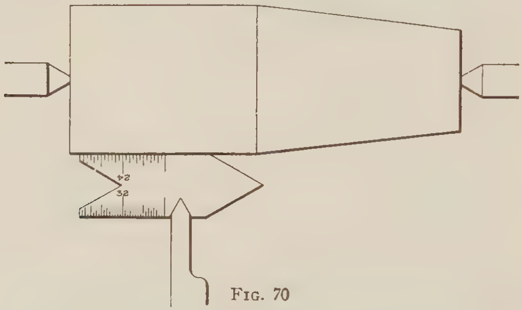


FIG. 70

spindle in case there is no straight part on the work. The **V** and United States threads are cut with the sides making equal angles with the axis of the taper, and the taper attachment produces true threads.

109. Height of Threading Tool When Cutting Tapered Threads.—It is very important that the top cutting face of the tool should lie at the same height as the axis of the taper. If the tool is set above the centers, it will change the angle of the sides of the thread and also form a curved tapering thread. These errors were treated in the articles on cylindrical threading, and in the Section on taper turning.

TESTING EXTERNAL SCREW THREADS

110. Calipering Threads.—Before the final testing in the gauge or work, the thread may be tried by the use of thread calipers. These calipers are made very thin on their points,

so that they fit into the **V**'s of the thread and measure the diameter at the root, as shown in Fig. 71. They may be set either from a tap or from a standard gauge.

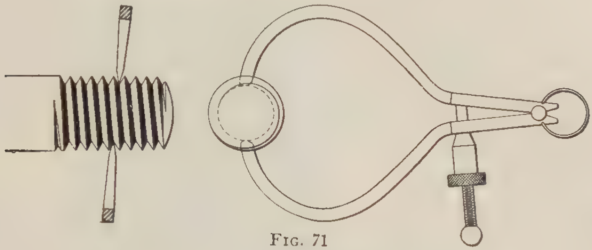


FIG. 71

111. Spark-Plug Limit Thread Gauges.—Limit thread gauges designed for testing the threads on the spark plugs of gas engines together with the threads in the tapped holes, are shown in Fig. 72. These limit gauges consist of two members known as a templet *a* having two threaded holes, and a plug *b* having two threaded parts and a sizing cylinder. Spark plugs have a diameter of $\frac{7}{8}$ inch and 18 threads per inch. The pitch diameter of the thread should measure between the limits .836 inch and .839 inch.

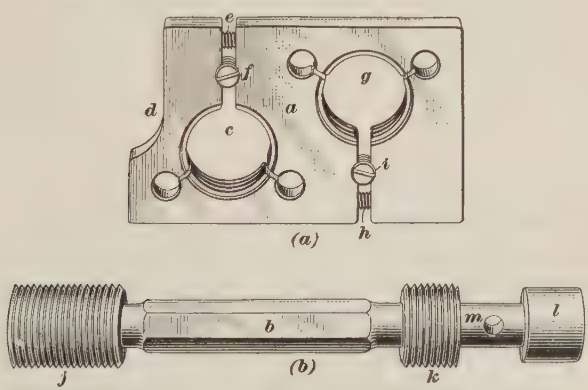


FIG. 72

In the templet *a* the threaded hole *c*, next to the cut-off corner *d*, is adjusted by the screws *e* and *f* to the "Go" size, which is for the pitch diameter of the threaded spark plugs.

The work must be finished so that it will go through the hole *c* easily. The size of the "No Go" hole *g* is adjusted by the screws *h* and *i* so that the threaded part of the spark plugs will not go through this hole. The screws *f* and *h* are tapered and are used for adjustment and the screws *e* and *i* are used for clamping. By the use of the screws the holes *c* and *g* in the templet *a* are set to the limits between which the pitch diameter of the threaded work must be made without being too large or too small for acceptance.

112. The plug *b* consists of a double-end threaded limit gauge *j* and *k* for testing the tapped holes. It also has a cylindrical end *l*, which is used to check the root diameter, or the size of the hole inside of its thread. The part *j* is fastened to the handle *b* by means of a long screw passing through it and into the handle. Part *k* is fastened to the handle *b* by means of the threaded end of the neck *m*. A rod may be used in the hole through the neck as a wrench to turn it.

113. Visual, or Shadow, Method of Testing Threads. A very rapid method of testing screw threads is to use on a screen a magnified outline of a true thread of the style being tested. See the description of the instrument, and the method of using it, in the lesson on *Precision Measuring Instruments*.

TESTING INSIDE THREADS

114. Moving Inside-Thread Tool From Work.—Most work that is threaded on the inside cannot be taken from the lathe and must be tested in place. The tool can be moved out of the way by reversing the lathe and allowing the carriage to feed back far enough to permit a thread plug gauge to be used; but this is a very slow way and is seldom employed. Sometimes it is possible to move the tool a sufficient distance to one side, by means of the cross-slide, to allow the gauge to be tried. If the tool is brought back to the stop after the work has been tested, it will be in place to continue the work

115. Another method is to stop the lathe and measure from the point of the tool to the work, as shown in Fig. 73. The split nut is then opened and the carriage is run back by

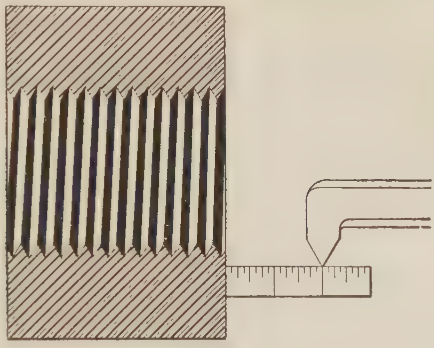


Fig. 73

hand. After testing, the tool can be moved back so that the measurement is the same as before and the feed-nut thrown in. Care should be taken that the spindle is not turned while the feed-nut is open, for it will cause trouble in getting the tool to start again in the correct place.

TURRET LATHES

CONSTRUCTION OF TURRET LATHES

TURRET LATHE TYPES AND ATTACHMENTS

INTRODUCTION

1. Uses of Turret Lathes.—Turret lathes are used to produce *duplicate* work, especially in large lots. Their special feature is a *turret a,* Fig. 1, which holds several tools and which may be revolved to bring the tools into action in a regular order, as needed for facing, turning, drilling, boring, reaming, threading, forming, cutting off, etc.

Duplicate work can be made faster on a turret lathe than on an engine lathe because the sequence of operations is repeated without resetting the tools. Each tool is swung into action quickly, and its movements do not depend entirely on the skill of the operator.

2. Classes of Turret Lathes.—There are two general classes of turret lathes known as *bar stock machines* and *chucking machines.* The first class is used to operate on any form or size of bar stock that can be passed through the lathe spindle. The second class operates on work held in a chuck or fixture. Combination machines are made to perform work of both classes. Numerous variations in the design and use of turret lathes have led to the adoption of such names as *screw machines, monitor lathes, flat turret lathes, vertical turret lathes, engine lathes with turret attachments, plain turret lathes, universal turret machines,* etc.

TURRET SCREW MACHINES

3. Hand-Operated Turret Screw Machine.—The turret screw machine, so named because it was first used for making screws, performs six or more operations on the end of a revolving rod as may be necessary to make screws, pins, rings, handles, and the like. The three general forms of turret screw machines are known as the *hand*, the *automatic*, and the *semi-automatic* screw machine.

4. General Arrangement of Hand Screw Machine.—A belt-driven hand turret screw machine is shown in Fig. 1. The movements of the turret *a*, turret slide *b*, cut-off rest *c*, feed of stock *d*, and turret slide bed *e* are by hand. The turret slide bed is clamped to the machine bed, while the turret is mounted on the slide *b*, which is moved to and from the headstock by a pilot wheel, or turnstile, *f*. The extent of the movement toward the headstock is regulated by one or more screw stops *g* in the end of the slide. The tools are held in the six holes in the turret *a* by clamp screws *h*, and a binder lever *i* clamps the turret to the slide.

5. The rod, or bar, stock *d* is fed through the headstock by the lever *j* acting on a clutch *k* that also operates the spindle chuck *l*, which grips the rod and causes it to revolve with the spindle. Floor stands *m* support the rod. Cut-off and turning tools are held in the front and back tool posts *n* and *o* on the cut-off slide rest *c* operated by the lever *p*. Oil is flooded onto the tools and work through the adjustable pipe *q*. The oil pan, shown at *r*, collects all the cuttings and the used oil, the oil being drained into the tank *s*. The oil is circulated from the tank *s* by either a rotary or a geared pump located on the back of the bed.

6. Wire-Feed Screw Machine.—In Fig. 2 is shown a screw machine of much more elaborate design than the plain machine in Fig. 1. The turret *a* has holes for eight tools. The spindle is friction-clutch driven from the cone by operating the lever *b*. The wire, or rod, stock is fed through the spindle by a roller feed in the headstock case *c*, and an automatic chuck *d*

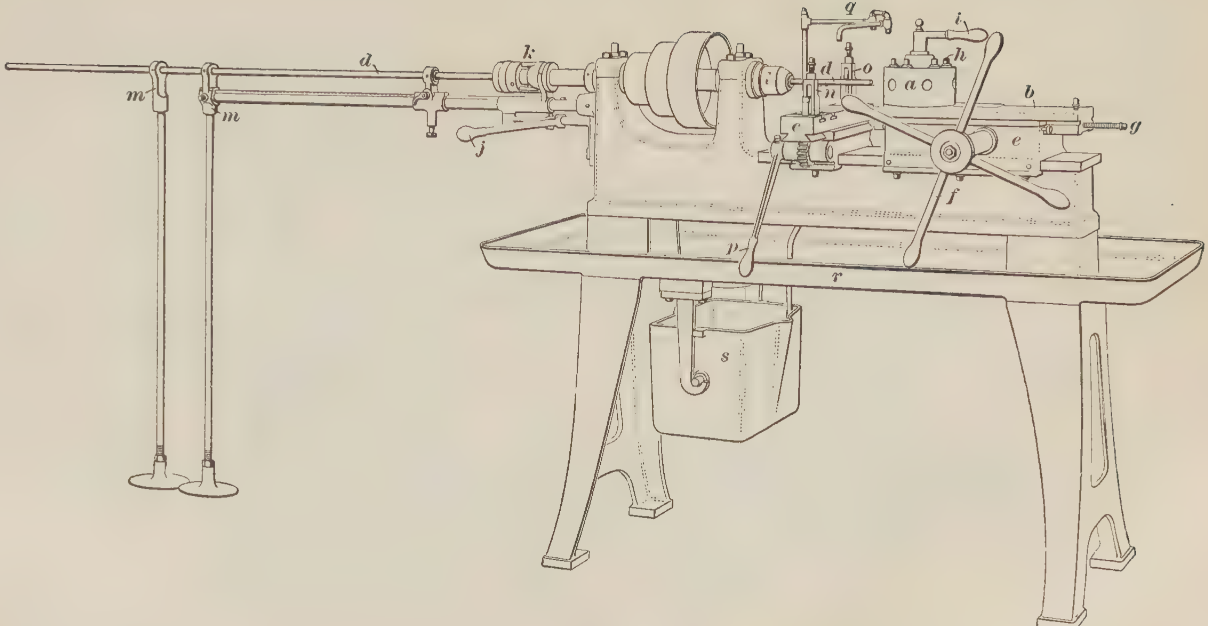


FIG. 1

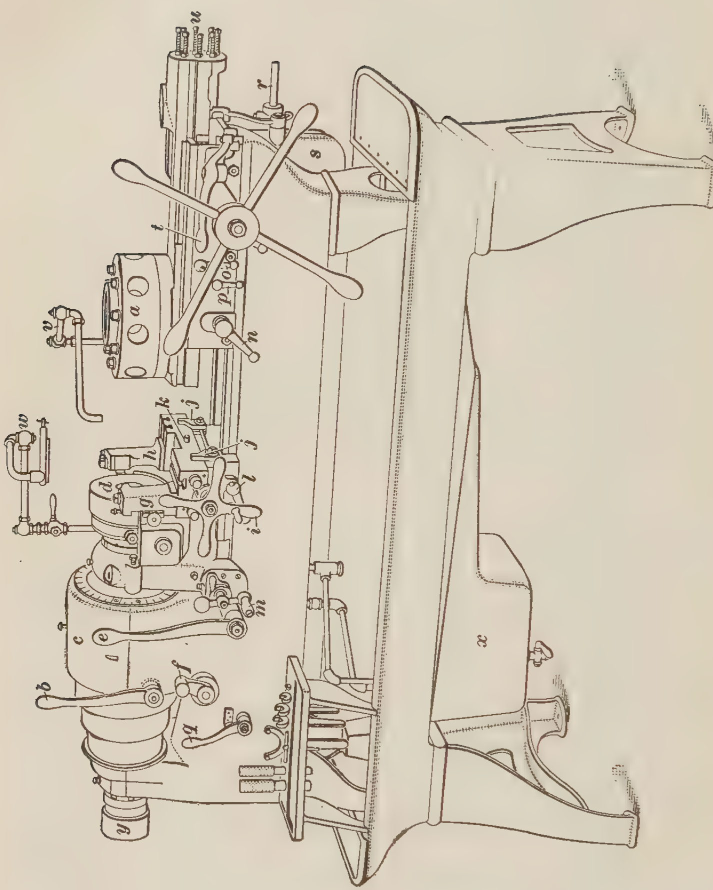


Fig. 2

for gripping the stock is mounted on the nose of the spindle. The roller feed and the chuck are operated together by the lever *e*. Moving the lever toward the left opens the chuck and feeds the stock forwards against the stop; returning the lever to a vertical position, as shown, closes the chuck and clamps the stock. The back gears for low speed are clutched in or out by the lever *f*.

The cross-slide has front and back tool supports *g* and *h*. The cross-slide screw is operated by the hand wheel *i*, and the cross-slide movement is gauged by two stops *j* clamped to the saddle, and a pin *k* projecting from the side of the slide. The saddle is clamped to the machine bed by the lever *l*, and the handle *m* moves the cross-slide lengthwise of the bed.

7. In the turret mechanism there is a lever *n* to clamp the turret-slide bed to the machine bed, and a lever *o*, to clamp the turret slide to its bed. Besides the hand clamps there is a lever *p* that operates a positive stop between the turret bed and the machine bed to take the end thrust from the tools, and to insure that there is absolutely no backward movement of the turret bed during the cutting operation. This is of special service when taking heavy cuts.

A lever *q* on the headstock operates a feed-change gear-set on the back of the headstock. This set drives the worm-gear shaft *r* that operates two trains of gears in the apron *s* that is attached to the back of the turret-slide bed. The long lever *t* back of the turnstile that moves the turret slide by hand, is used to throw in or out the power feed of the turret slide. The worm on the shaft *r* may be meshed with either of the two gear-trains in the apron and a feed-variation from fine to coarse obtained. A set of eight screw stops *u* limits the feed-motions of the tools.

The oil piping is double, one part *v* supplying oil or coolant to the tool and the other *w* to the work. The oil is collected and strained in a reservoir *x* in the base of the machine and circulated by a rotary pump. A centering guide *y* on the rear end of the spindle holds the bar stock in line with the spindle.

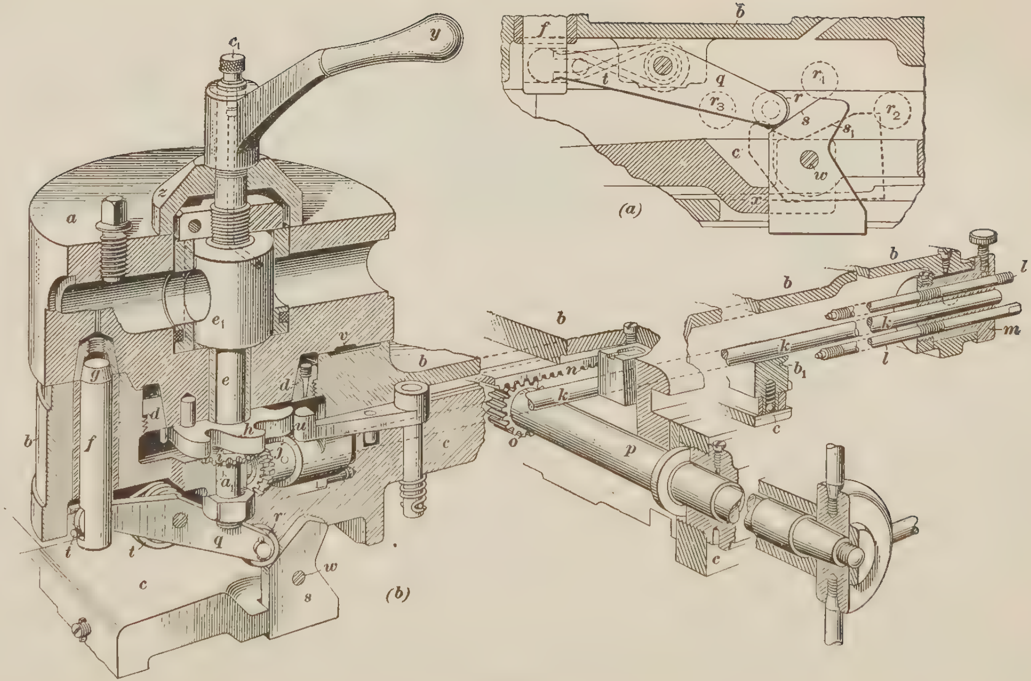


FIG. 3

8. Hand Screw Machine Turret and Slide.—The construction of the turret and slide of a hand screw machine of the type illustrated in Fig. 1 is shown in Fig. 3. This is a vertical section through the middle of the turret *a*, slide *b* and saddle *c*, with conventional sections of parts that are located either behind or in front of the middle section.

The turret *a* is centered in a conical ring bearing *d*, adjustable for wear in the slide *b*, and it is held down by a stud *e*, which is enlarged at the center at e_1 and bored to permit of passing the stock through it. A lock-bolt *f* moves vertically in the slide *b*, and its upper end *g* fits a bushed conical hole in the bottom of the turret. There are six of these holes—one for each tool position, which insures that the turret is set correctly to center the tool on the work after each indexing.

9. A six-tooth ratchet *h* attached to the bottom of the turret is used to index the turret, and a bevel gear *i*, also fastened to the turret, operates the stop-system through a bevel gear *j* and a horizontal shaft *k*. Six stop-screws *l* threaded nearly their full length are located in a head, or carrier, *m* on the outer end of the shaft *k*. The slide *b* is moved back and forth by a rack *n* on its under side, which is driven by a pinion *o* on the end of the turnstile shaft *p*.

10. Turret Action of Hand Screw Machine.—The action of the hand machine turret consists of means to move the turret forwards and backwards in its relation to the headstock, to revolve, or *index*, the turret one-sixth of a turn as required by each succeeding tool, to clamp the turret, and to gauge the lengths of cuts on the rod stock by a system of stops. The turret *a*, Fig. 3, is indexed by the motion of the slide *b* as follows:

The backward movement of the slide *b* withdraws the lock-bolt *f*, by means of the trip lever *q*. The advancing end of the trip lever with its roller *r* rides up the incline on the tumbler *s*, to the position shown by the dotted circle r_1 in view (*a*), and causes its other end that engages the lock-bolt *f* to draw the bolt downwards against the action of the spring *t* and out of its bushing in the bottom of the turret. Immediately following this

action of releasing the turret a tooth on the ratchet *h* attached to the turret engages the finger, or *pawl, u* on the saddle *c,* which forces the turret to make one-sixth of a turn during the full backward stroke of the slide *b.* While the turret is revolving, the end of the lock-bolt *f* projects into the groove *v* in the bottom of the turret and enters the hole corresponding to the next tool position.

During the forward, or return, motion of the slide *b,* the trip roller *r,* on returning from its extreme right-hand position r_2, strikes the tumbler *s,* which is pivoted at *w.* The tumbler is gradually pushed over and assumes the position s_1, shown by the dotted lines, and the roller returns over the tumbler without being lifted, leaving the lock-bolt *f* undisturbed. When the roller reaches its extreme left position, such as at r_3, it clears the tumbler, which automatically rights itself again into the position *s,* owing to the greater part of its weight being below the pivot *w.* A stop *x* that is part of the saddle *c* prevents the tumbler *s* from turning to the right. Thus, the unlocking and indexing motions are performed with each full backward and forward movement of the slide *b.* When the return stroke is completed the lock-bolt *f* enters a hole in the turret. The turret is clamped by turning the binder handle *y* right-handed on the threaded stud *e* against the binder washer *z.* The stud *e* is held from turning by a key a_1 in the slide *b.*

11. When the turret is indexed the bevel gears *i* and *j,* the shaft *k,* and the stop-screw carrier *m* also make their proportional turn. Each stop-screw *l* must be adjusted through the carrier *m* for the length of cut required of its corresponding tool. The inner end of the stop-screw strikes against a stop-block b_1 and prevents any further forward movement of the turret. Oil is fed into the turret mechanism through a hole in the stud *e,* this hole being capped by a plug c_1.

12. Turret-Lathe Headstock.—In some turret lathes the headstock and bed are cast in one piece to make the lathe more rigid. In other types the head is bolted to the bed. The spindle is ground and lapped so as to make a good fit in the bearings, and in most designs the spindle bearings are adjustable.

When the work is small or requires high speed, the bearings are adjusted for greater clearance than for heavy work at slow speeds.

13. Geared Headstock.—A geared turret-lathe headstock is shown in Fig. 4. On the shaft *a* at the rear of the headstock, driven by the pulley *b*, are four gears *c*, *d*, *e*, and *f*, that mesh with the gears *g*, *h*, *i*, and *j*, respectively, loose on a second shaft

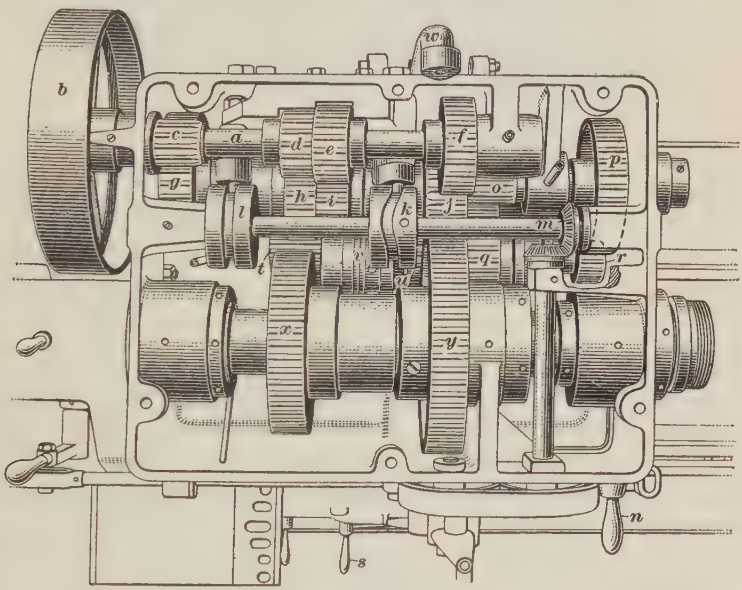


FIG. 4

underneath the shaft *a*. Between the latter gears are friction clutches controlled by two cylindrical cams *k* and *l* that are operated through the bevel gears *m* by a handle *n* at the front of the headstock. Any one of the four loose gears on the second shaft may thus be engaged, giving four speeds to this shaft.

On the right-hand end of the second shaft are two gears *o* and *p* that drive the gears *q* and *r*, loosely mounted on a third shaft below the others. Between these loose gears is a friction clutch operated by the handle *s* in front of the headstock. By

shifting the two handles *n* and *s* the third shaft can thus be run at eight different speeds.

14. On the left end of the third shaft are placed two sliding gears *t* and *u*, with a friction clutch *v* between them, operated by an arm *w* in the back of the headstock. These two

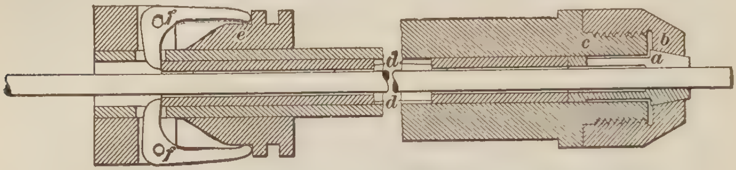


Fig. 5

gears mesh with the two main driving gears *x* and *y* on the main spindle. By manipulating the handles *n* and *s* in front of the headstock and the arm *w* in the back, sixteen changes in spindle speed may be obtained while the lathe is running. The reverse is made to the pulley *b* from the countershaft. A rod extends from the arm *w* in the back of the headstock to a convenient location for the operator.

15. Push-Out Screw-Machine Chuck.—The chuck *l* and clutch *k*, Fig. 1, are shown in detail in Fig. 5. The grip of the rod stock is accomplished by pushing the split collet *a* into the tapered hole in the end of the cap *b*, the cap being screwed to the nose *c* of the lathe spindle. In Fig. 6 is shown the collet *a* removed. In gripping the work, the collet is pushed into the cap *b*, Fig. 5, by means of the hollow tube *d*, which passes through the lathe spindle and the clutch at the rear end. The end of the tube *d* bears against the inner ends of the two levers *f*. These levers are operated by the cone-shaped piece *e*, which slides over the spindle.

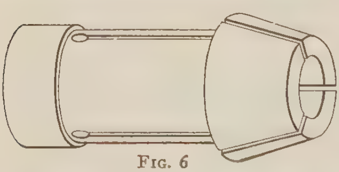


Fig. 6

When the cone *e* is moved to the position indicated, the outer ends of the levers *f* are forced apart, which moves their inner ends against the end of the tube *d*. This operation pushes the tube through the spindle and against the collet, thus

causing it to grip the work. When the cone *e* is moved back, the long ends of the levers move in and relieve the pressure on the end of the tube *d*. Springs are arranged to open the

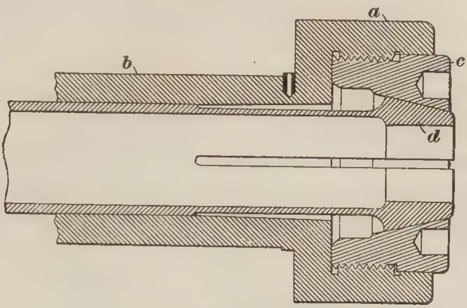


FIG. 7

chuck as soon as the cone *e* is removed from under the levers *f*.

16. In the form of chuck shown in Fig. 7, the head *a* of the spindle *b* is threaded internally to receive the tapered collet ring *c*. As the collet *d* extends back into the spindle, this arrangement reduces the overhang of the spindle and the collet from the spindle bearing, and gives a more rigid support to the stock.

17. Ratchet Feed for Feeding Heavy Bars Through Spindle.—A way to feed large and heavy bars through the spindle

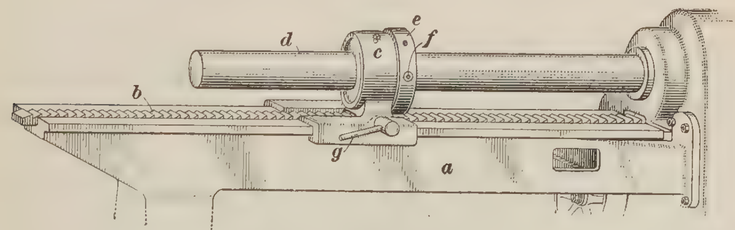


FIG. 8

is shown in Fig. 8. An extension *a* is bolted on the head end, and carries a long ratchet *b* and a sliding head *c*. The bar *d* is clamped in a revolving bushing *e* by four countersunk setscrews *f*. By moving the lever *g* a pawl on the lever shaft

engages with the ratchet *b* and causes the sliding head *c* to move forwards to feed the bar stock *d* through the spindle. Operating the collet in the machine spindle may also cause the ratchet *b* to move forwards together with the sliding head *c* and feed the stock bar *d* forwards.

UNIVERSAL MONITOR LATHE

18. Description.—A turret lathe that is extensively used for brass work and for work that is not made on the ends of rods, is the monitor lathe, shown in Fig. 9. This lathe lacks

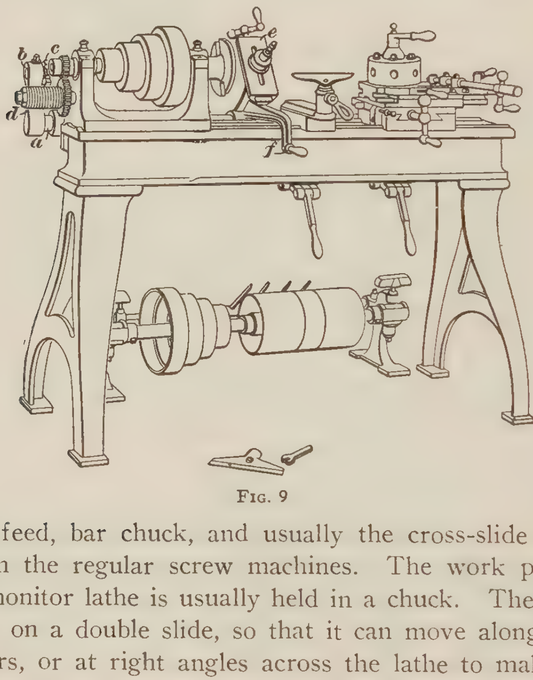


FIG. 9

the rod feed, bar chuck, and usually the cross-slide carriage, found on the regular screw machines. The work performed by the monitor lathe is usually held in a chuck. The turret is mounted on a double slide, so that it can move along the line of centers, or at right angles across the lathe to make facing cuts. This gives a combination of two movements for the turret that is not used on the screw machines. In some designs the headstock moves across the lathe.

19. Thread-Chasing Attachment on Monitor Lathe. Besides the method of cutting screws by dies in the turret,

the monitor lathe has a special attachment for chasing threads. At the back of the lathe is a round chaser bar *a*, Fig. 9, which is free to move in the direction of its length. Near the middle of the bar a slide rest *e* is attached, that holds the tool post for the threading tool set back of the work. To the headstock end of the chaser bar *a* an arm *b* is rigidly attached. On the end of this arm a follower *c* is fastened, on which a few threads are cut similar to those in a half nut. These threads engage with the short screw *d*, seen on the stud of the lathe. When thus engaged, as the lathe revolves, the threads on *c* follow the threads in the screw *d*. This motion feeds the chaser bar *a* through its bearings, and moves the threading tool along the work.

20. Extending over the bed to the front is a lever *f*, Fig. 9, to be operated by hand. Lifting the lever *f* causes the chaser bar to turn in its bearings and the follower *c* and the screw *d* are disengaged. The bar can then be moved with the tool rest

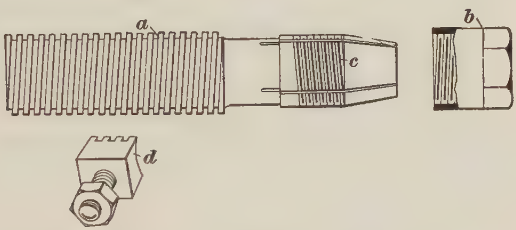


Fig. 10

back to its starting point. Parts to be threaded may be held in a chuck, or on an arbor in the spindle, or in a chuck at one end and supported at the outer end by a center carried in the turret.

21. Suppose that a center is put in the turret and the work is held between centers to have a thread cut. The tool is adjusted in the tool post of the slide *e*, Fig. 9, so that it just touches the work when the piece *c* is against the screw *d*. As the lathe revolves, the tool is drawn along and a thread of the same pitch as the screw *d* is cut on the work. When the thread has been cut, the lever *f* is lifted, and the tool is raised

from the work and, at the same time, the follower *c* from the screw *d*. The bar is then moved back to the starting point, the tool moved forwards a little on the slide *c*, and the lever *f* is dropped and the second cut taken. This operation is repeated until the required depth of thread has been cut. Only short threads can be cut by this method, and the screw *d* must be changed for every different pitch. This method is extensively used in cutting threads on brass pipe, valves, and similar work.

22. Leaders, or Master Threads.—The screw *d*, Fig. 9, is a shell that fits over the stud. Such screws are called *leaders, hobs,* or *master threads.* In Fig. 10 is shown a leader *a*, and a screw collar *b* to clamp its split end *c* to the stud of the lathe.

In Fig. 9, the leader *d* is geared 2 to 1 to the spindle. The pitch of the leader thread in this case is double the pitch of the thread to be cut. In some types of monitor lathe the leader is put on the spindle, in which case its pitch must be the same

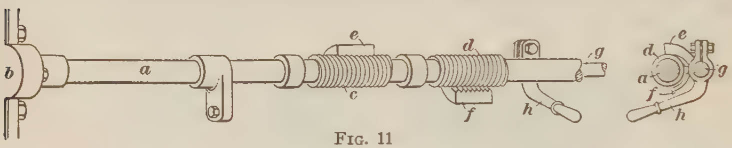


Fig. 11

as the pitch of the thread to be cut. Leaders are usually made of tool steel, but do not have to be hardened, and the followers are made of brass.

23. Cutting Left-Hand Threads With Chasing Attachment.—When it is desired to cut a left-hand thread with a leader arranged to cut a right-hand thread, it becomes necessary to reverse the motion of the leader. This may be done by introducing an idler gear on a swinging bracket between the spindle gear and the leader gear. In other types of lathe the rotation of the spindle is reversed in cutting left-hand threads.

24. Quick-Return Chasing Attachment.—Where two or more cuts must be taken in threading a large number of short pieces, it is a great advantage to use some means for returning the tool quickly to the starting point. One form of attachment for this purpose is shown in Fig. 11. The feed-rod *a*

is operated continuously from the geared end *b* of the headstock. This rod has a leader *c* that moves the carriage while the tool is making the cut. There is also a leader *d* having a left-hand thread of much greater lead than the thread on *c*, and which returns the carriage to the starting point. The follower *e* for the leader *c* and the follower *f* for the leader *d* are both attached to the rod *g* that moves the tool carriage. A hand-lever *h* is also clamped to the rod *g*. The arrangement is

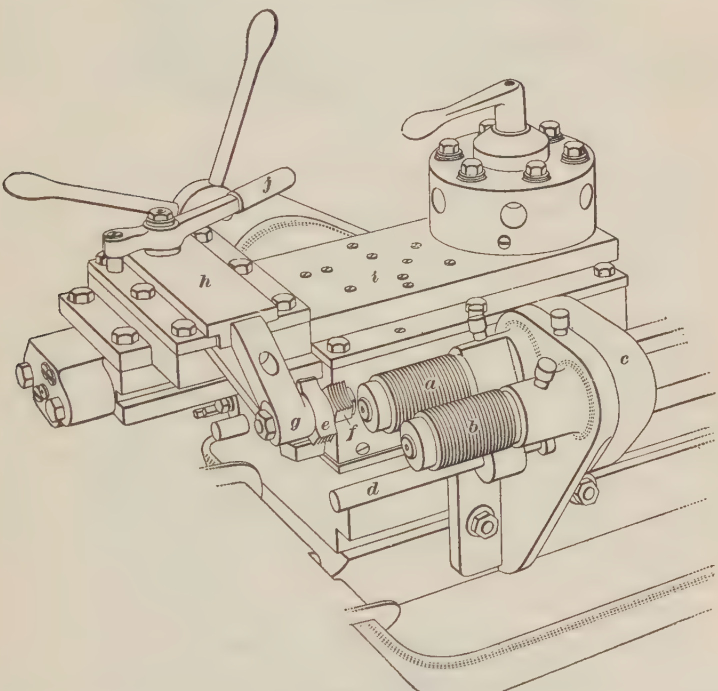


FIG. 12

such that by the use of the lever *h* either the follower *e* or *f* can be meshed with its respective leader *c* or *d*. Furthermore, the lever may be set in the mid, or neutral, position so that neither follower will mesh, and the tool carriage must then be moved directly by hand in the usual way.

25. Two-Lead Chasing Attachment.—The chasing attachment shown in Fig. 12 is arranged for cutting threads of two

different leads. The two leaders a and b are carried on studs on the gear-box c fastened to the back of the bed, and are driven by gears from the feed-rod d. The followers e and f

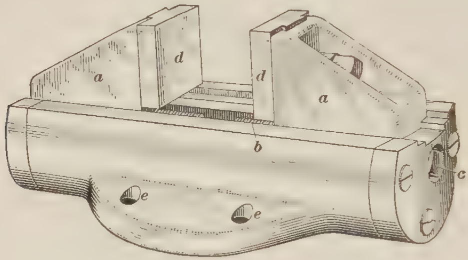


FIG. 13

are attached to the side of an extension g from the cross-slide h on top of the turret slide i. The extension g is moved over the top of the leaders by the handle j and the follower e or f connected to its respective leader, a or b.

26. Box Chucks for Monitor Lathes.—Chucks made to fit the outline of the work, or *box chucks,* are used on monitor lathes. In Fig. 13 is shown a two-jaw square-surface box chuck. The jaws a are moved in or out by a right-hand and left-hand screw b operated by a socket wrench applied at c. The cast-iron false jaws d are dovetailed into the sliding jaws. The body is made of steel. Four bolts through holes e attach the chuck to the face plate.

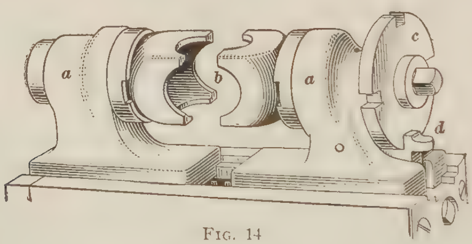


FIG. 14

27. Revolving-Jaw Chucks.—In addition to the sliding jaws a as shown in Fig. 13, box chucks have jaw grips that may revolve. The grips b, Fig. 14, are for holding globe valve

bodies, elbows, tees, etc., so that several faces may be finished with one chucking.

An index plate *c*, with four notches, is used to set the machined surfaces of the work at right angles to each other. A latch *d* holds the plate.

For duplication work the time saved by using the revolving-jaw chuck is often enough to warrant the use of raising blocks under the headstock and the turret to provide for the increased swing needed by the chuck.

28. Cross-Slide Carriage on Monitor Lathes.—The cross-slide carriage shown in Fig. 15, for use on monitor lathes, has

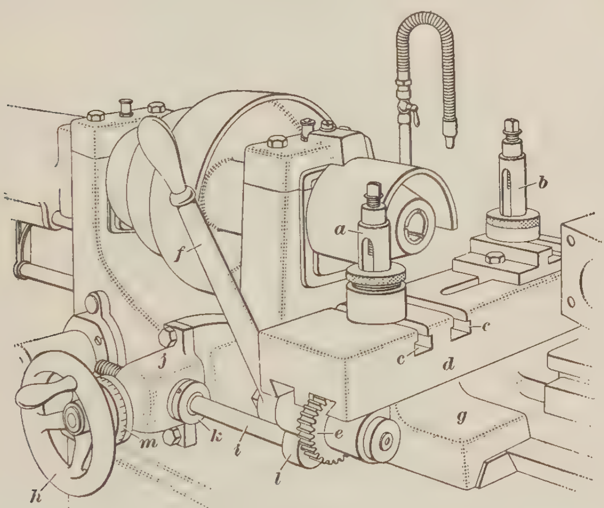


FIG. 15

front and rear tool posts *a* and *b*. The front tool post may be fitted into either one of two T slots *c* in the top slide *d*. A rack under the top slide *d* meshes with the gear *e* on the same shaft as the handle *f*, and thus the top slide may be moved back and forth on the saddle *g*.

The carriage is moved lengthwise of the bed by the hand wheel *h*, which transmits motion to a shaft *i* by means of a pair of bevel gears inside the housing *j*. This housing has a threaded bushing *k* through which the threaded end of shaft *i*

passes. The other end of the shaft *i* is fastened to the carriage at *l*. When the shaft *i* is turned in the threaded bushing *k*, the shaft will move the carriage. A graduated dial *m* on the hand wheel shows the distance that the carriage is moved.

FLAT TURRET LATHE

29. General Features of Flat Turret Lathe.—The flat turret lathe shown in Fig. 16 consists of the usual bed *a* with a pan *b* to catch chips and oil. It is operated through a geared head *c* that has a movement at right angles to the carriage **V**'s. A lever *d* operates the bar chuck. An ordinary chuck is used for plain chuck work; an automatic chuck is used for bar work.

30. The lever *e* controls the back gears, giving three speeds, and the lever *f* gives the additional geared speeds. A plain carriage *g* carries the flat turret and tools on its top; it is operated through the apron *h* at the front of the lathe. A feed-rod *i* moves the carriage by power through gearing; but the carriage may also be moved by hand by use of the capstan wheel *j*. The finished work is cut from the bar by a cutting-off tool operated by the tool lever *k* on the turret. The capstan wheel *l* is used to operate the cross-feed by hand. The automatic feed of the carriage is thrown in and regulated by the lever at the front of the carriage; and nine different feeds may be obtained by the lever *m*. A belt-driven oil pump circulates the oil from the reservoir in the bottom of the pan. The head is driven by a belt on the pulley *n*, and the shifter *o* provides for starting, stopping, and reversing the spindle.

31. Roller Feed for Bars.—While the lathe is in motion the bar is fed through the spindle by the roller feed shown in Fig. 17. The outer shell, which carries the bearings of the shafts to which the gears are fixed, is fastened to the lathe spindle and turns with it. While the operation is being performed, the outer shell, the spiral gear *a*, and the spindle all rotate together, and the gears inside the shell have no relative motion. But when the bar chuck is opened a pin is pushed

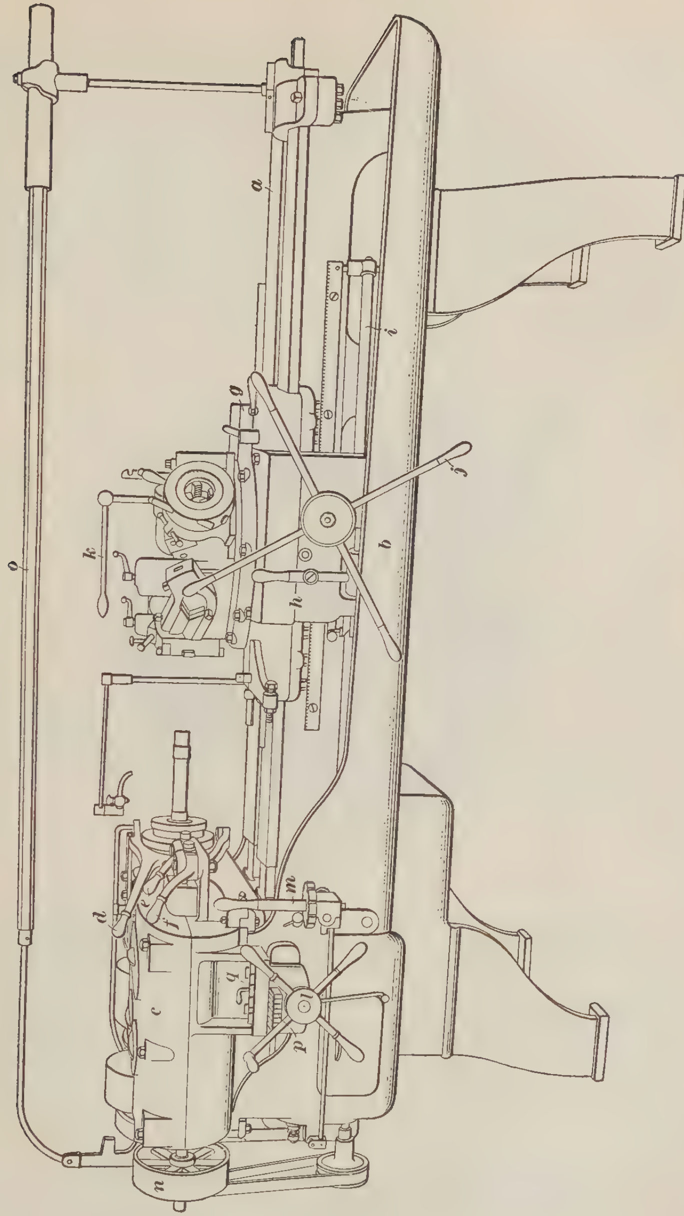


Fig. 16

forwards and catches one of the lugs on the outer face of the gear *a*, preventing this gear from turning. The shell of the roller feed continues to turn with the spindle, and consequently two spiral gears *b* are turned by being moved along the edge of the stationary gear *a*. Each of the gears *b* is on a shaft that carries a right-hand worm *c* and a left-hand worm *d*. The worms in turn rotate the worm-gears *e* and *f* that cause the rolls *g* to feed the stock or bar through the spindle. The

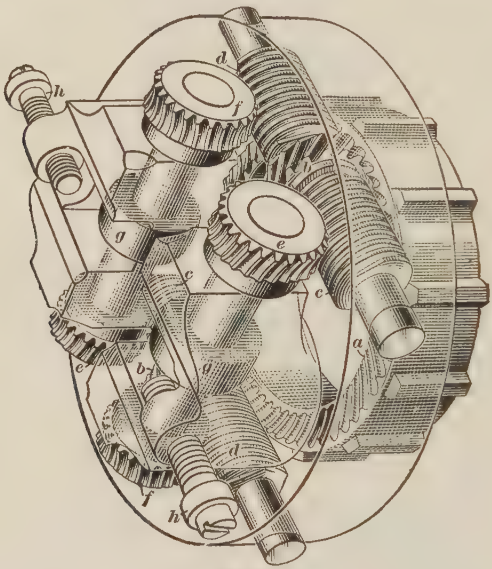


FIG. 17

rolls are adjusted to their proper working distance by two screws *h*. A scroll chuck at the back of the roller feed brings the bar central with the spindle and the rolls are set in motion, when the bar chuck is opened, by the same lever that opens and closes the chuck. The bar is fed up against the stock stop where it is held by the rolls until the chuck is closed; this stops the roller movement.

32. Roller Turner.—A form of roller turner used on a flat turret lathe is shown in Fig. 18. The cutting tool *a* is clamped firmly in the block *b* by the setscrews *c*, and the work

to be turned passes between the tool and the rollers *d*. The block *b* is movable, its position being controlled by a lever *e*, and thus two different diameters may be turned with one tool. When the lever is thrown forwards as far as it will go the tool is in its farthest position from the rollers and cuts to the greatest diameter on the work; but when the lever is drawn back to the position shown, the tool is forced closer to the work and cuts to a smaller diameter. The travel, or swing, of the lever is adjusted by the screws *f*. The rollers are held in brackets

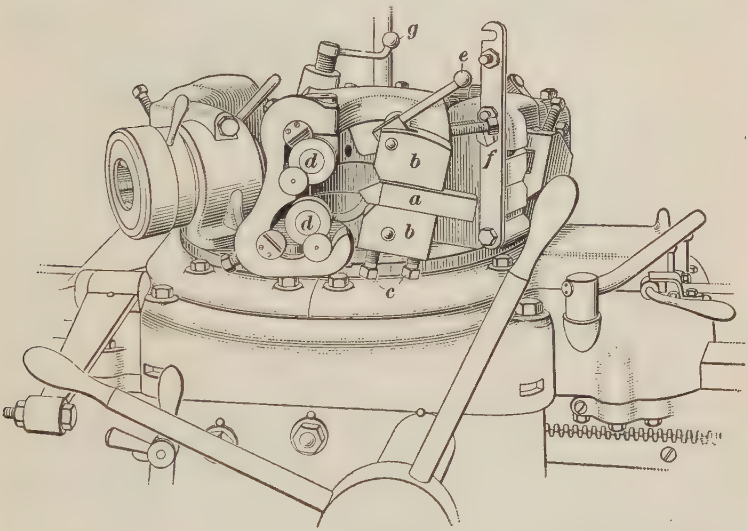


FIG. 18

and may be swung closer together or farther apart by turning the handle *g*, thus setting them to suit different sizes of work. Also, the rollers may be moved sidewise on their pins, so that they bear either on the part that is to be turned or on the part that has been turned; that is, they are not directly opposite the tool. The positions of the rollers can be adjusted very accurately by setscrews at the back.

33. Construction of Flat Turret.—The flat turret *a* shown partly in section in Fig. 19, consists of a flat circular plate that has a large flat bearing on the carriage *b*. It is held in place

by the center pin *c* on which it rotates and by the circular gib *d* that is screwed to the carriage. The tool holders have tongues on their lower surfaces, and these tongues are set in the slots *e* in the plate *a*, after which the holders are bolted firmly to the plate. The turret is rotated on the pin *c* to bring each tool into position for cutting. The rotation is accomplished by turning the pilot wheel and running the carriage back until the end of the rack *f* strikes a back stop fixed to the bed of the lathe. As the carriage continues to move, the rack is pushed

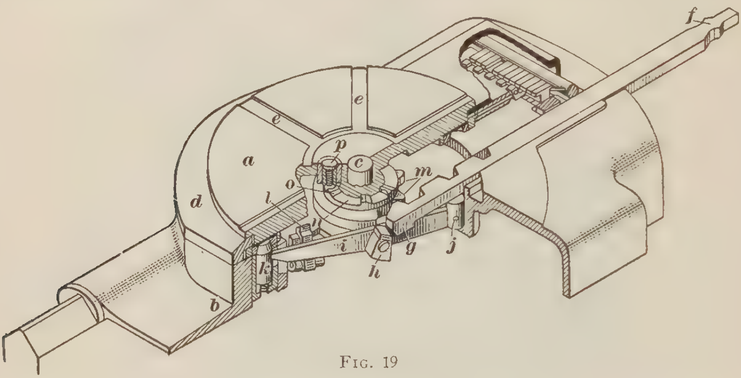


FIG. 19

into the turret and the end *g* strikes the pawl *h* on the lever *i*, which is pivoted at *j*. The lever is thus forced down, and its free end pushes the pin *k* down, and thus frees the turret plate *a*. The latch *l* then hooks over the lever *i* and holds it down while the plate is being turned.

34. The turning of the plate *a*, Fig. 19, is done by the rack *f*, which is notched so as to engage the teeth *m* on the ratchet gear *n*. The rack is held stationary by the back stop, and the movement of the carriage brings one of the teeth *m* of the ratchet gear *n* against the rack and so turns the gear. The projection *o* on the upper face of the ratchet gear catches the pin *p* and thus turns the turret plate *a*. When the plate has turned almost to its correct position, a screw not shown in the illustration strikes the latch *l* and unhooks it from the lever *i*, thus allowing the pin *k* to be forced up by the spring beneath it. When the turret rotates to its proper position, the pin *k*

springs up into a hole or bushing in the under side of the turret plate and locks it in place. The tool is now fed up to the work by turning the pilot wheel. As the carriage is moved up, the rack *f* is held for a moment by a clip that fits over the lugs at its outer end. The rack is thus pulled out again to the position shown, ready for the next rotation of the turret. When the rack is thus moved out, the ratchet gear *n* turns backwards freely under the pin *p* without moving the turret. When the carriage has moved forwards far enough to return the ratchet gear to its original position, the rack strikes a stop on the carriage and is brought forwards with the carriage and is thus drawn away from the clips.

35. Flat Turret Stop-System.—In the turret lathe shown in Fig. 16, the movement of the carriage, and consequently the travel of the tool, is limited by a system of stops and stop-bars, as shown in Fig. 20, in which (*a*) is an enlarged view of a part of the mechanism shown in (*b*). The stop-bars *a* consist of twelve rectangular bars, known as *A* stop-bars and *B* stop-bars. One of each corresponds to each of the six divisions of the turret, as indicated by the numbers *A 1* and *B 1*, *A 2* and *B 2*, etc. The object of using two stop-bars for each division of the turret is to allow two successive movements to be given to a tool during one operation. Above the ends of the stop-bars is a series of twelve stop-bolts *b*, one for each bar, known as *A* stop-bolts and *B* stop-bolts, and standing vertically in a slot in the carriage *c*. The upper end of each bolt is formed with a **T** head, and a lifting crank *d* pivoted on the carriage has a tongue that fits under the **T** heads of each pair of stop-bolts; that is, there are six lifting cranks to the twelve stop-bolts. Behind each lifting crank and bearing against its back face is a tappet rod, one of which is shown at *e*. This tappet rod extends from the crank to the face *f* of the turret.

36. While the turret is being turned, one end of the tappet rod *e*, Fig. 20, bears against the circular face *f* and the other end presses against the lifting crank, holding it up and thus preventing any of the stop-bolts from dropping lower in the slot. When the turret has turned so as to bring the tool in the

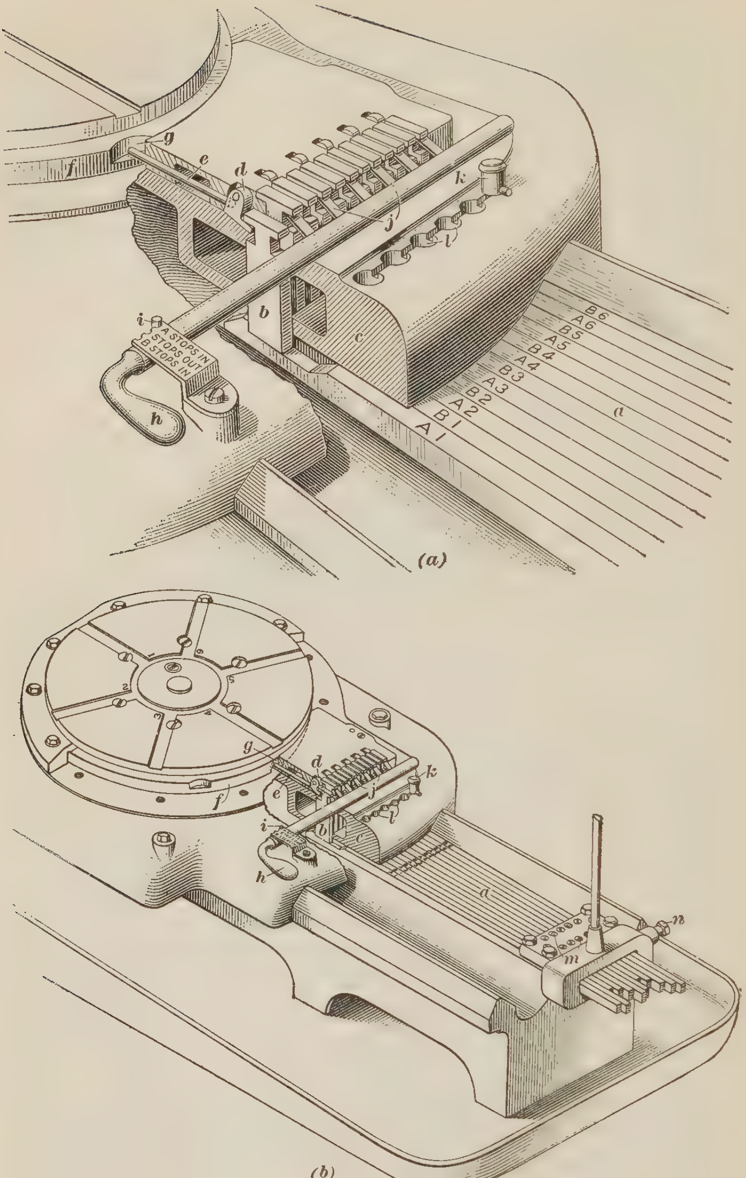

A STOPS IN
STOPS OUT
B STOPS IN
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
A6
B6
(a)
(b)

FIG. 20

first section to the proper position, the pin *k*, Fig. 19, springs into its bushing and locks the turret in position, as already explained. When the turret reaches this position, the recess *g*, Fig. 20, stands opposite the end of the tappet rod *e*. The *A 1* stop-bolt *b* then falls of its own weight, turning the lifting crank *d* and forcing the end of the tappet rod *e* into the recess *g*. The stop-bolt *b* now rests on top of the *A* 1 stop-bar, and the turret is locked in position with the tool clamped in its holder in slot *1* ready to perform its work. The carriage is now moved up toward the headstock, thus bringing the tool against the work. During this movement the stop-bolt *b* simply slides along the top of the corresponding stop-bar; but as it comes near the end of the stop-bar it falls into the notch cut in the upper surface of the bar. Further movement of the carriage brings the stop-bolt against the square shoulder, as shown, and the movement of the carriage is stopped; in other words, the meeting of the stop-bolt and the shoulder of the notch in the stop-bar determines how far the carriage shall move, and therefore how far the tool shall travel.

37. If only one stop is used for each numbered section of the turret, it will be necessary to employ only six stop-bars and stop-bolts. The other six stop-bolts are then held out of action by a simple device consisting of a series of lifters operated by a handle. In the particular case shown, the *A* stops are being used, and the handle *h*, Fig. 20, that controls the lifters is set so that the pin *i* in the rod attached to the handle is in the notch marked *A stops in*. Along the sides of the rod are six lifters *j* that fit under the **T** heads of the six *B* stop-bolts and hold them up, so that they cannot drop even when the tappet rod enters the recess in the turret plate. In this way only the *A 1* stop-bolt will act to stop the travel of the tool on section *1* of the turret. If two stops are used on one section, as section *1*, the handle *h* is first set as shown, and the *A 1* stop is used. Then the handle is moved so that the pin *i* is in the slot marked *B stops in*, and this throws the lifters *j* under the *A* stop-bolts and allows the *B* stop-bolts to act so as to limit the travel of the tool for the next cut. The action of the *B* stop-bolts is exactly the

same as that of the *A* stop-bolts. If it is desired to prevent either set of stops from acting, the lever *h* is turned so that the pin *i* is in the central notch. This process moves one of the lifters *j* under each pair of stop-bolts, and none of them can drop.

38. There are six tappet rods like *e*, Fig. 20, one corresponding to each lifting crank. Also, there are six recesses like *g* in the turret plate, one for each section of the turret, and these recesses face up and down alternately. When the turret is turned and one of these recesses swings past the ends of the tappet rods, the weight of the stop-bolts forces the tappets into the recess, one after another. But the recess has sloping sides, so that, as the turret continues to turn, the tappets are forced out again, lifting the stop-bolts that have dropped. When the turret reaches its new position and is locked by the pin under the turret plate, a recess is opposite the end of the tappet rod corresponding to that particular section, and the tappet rod moves into it. The other five tappet rods now bear against the face *f*, and so keep the other five lifting cranks from turning, which in turn prevents their stop-bolts from dropping. The six recesses in the turret plate are not equally spaced around the plate, but are cut so that each is opposite the proper tappet rod when its corresponding turret section is in use. After a stop-bolt has acted to stop the carriage it is lifted to its original position either by shifting the handle *h* or by turning the turret to a new position, which would force the tappet rod out of the recess and so turn the lifting crank and raise the stop-bolt.

39. If more than two steps must be used to give the desired movements to a tool, the auxiliary stop-pin *k*, Fig. 20, may be placed in one of the holes *l* so as to act on one of the *B* stop-bars that is not in use with the *A* or *B* stops. This pin is put in and removed by hand, and acts in the same way as a stop-bolt; that is, it rides along the stop-bar until it falls into the notch and stops the carriage. If the carriage is to be stopped while feeding backwards, or away from the chuck or headstock, the stop-bar should be turned upside down, so that

the stop-bolt will come against the squared end. Each stop-bar is adjusted with the turret turned to its proper position and the tool run to the limit of its cut. The position of each bar after adjustment is maintained by tightening the set-screws *m*, and after all the bars are set, they are clamped tightly by the screw *n*.

40. The stop-system just described limits the travel of the tool parallel to the **V**'s of the lathe. A system of stops is also used in connection with the movable head, which is so arranged that it can be moved at right angles to the **V**'s. This movement enables shoulders to be cut and facing cuts to be

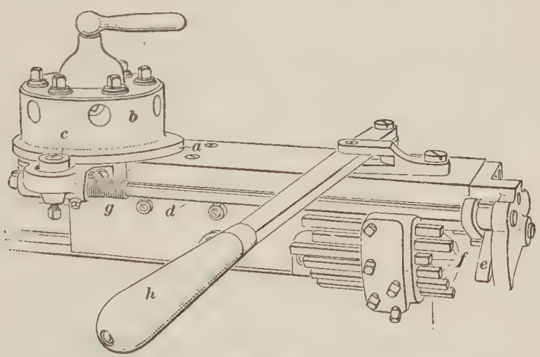


Fig. 21

made. The cross-stops for the head consist of nine rectangular notched bars *p*, Fig. 16, set crosswise of the bed under the head. They resemble the stop-bars already described and are set in a similar manner. There is only one stop-bolt, however, as at *q*. In the casting above the stop-bars are nine bushed holes corresponding to the bars. The stop-bolt is dropped by hand into any desired hole, and the pin then rides on the bar until the head is moved as far as it should go, when the bolt drops into the slot in the bar and prevents further motion. The notches in the bar have square shoulders at both ends, and the bolts may be used to stop the motion of the head in either direction. The stop-bolt must be shifted by hand for each different movement of the head. The head may quickly be brought to a central position for bar work.

41. Cam Operated Stop-System.—In Fig. 21 is illustrated a stop-system operated by a cam *a* on the bottom of the turret *b*. The cam *a* not only has a larger diameter than the turret *b* but it is not concentric with the turret. Therefore, when the turret is revolved during indexing, the wide part of the cam at *a* gradually moves the roller *c* outwards and revolves the shaft *d* to which the roller is pinned. As a result the shaft swings an attached arm *e* through a short arc during each indexing, and the arm *e* is thus set in line with one of the stops *f*. When the turret slide has moved toward the spindle as far as it should in taking the cut, the arm *e* strikes one of the adjustable stops *f*, and halts the slide motion. The arm *e* is swung from one stop to the next as the turret is indexed. The further rotation of the cam allows the roller *c* to return to its nearest position to the turret.

The rotation of the shaft *d* is against the tension of the spring *g*, which keeps the roller *c* always in contact with the cam. The slide is operated by the lever *h*.

VERTICAL TURRET LATHE

42. General Features.—The vertical turret lathe is a combination of an engine lathe, a horizontal turret lathe, and a vertical boring mill. Its main features are the rotating chuck, or table, of the boring mill, and two tool-carrying turret heads, one main head and one side head, both carried on rails fitted to the vertical bed. The two heads may be operated at the same time or independently.

43. The main head may be moved vertically and horizontally by power independent of the feed-mechanism or the table drive. Hand operation is used to move the side head in either direction. The feed-mechanisms, one for each head, are mounted at the rear of the rails and are driven by a vertical shaft revolving in a constant ratio with the table. The table spindle has a conical thrust bearing and the table is driven by a bevel pinion that meshes with a circular rack at the bottom of the table.

An oil pump driven from the main pulley furnishes continuous lubrication to the spindle, table drive gear and pinion, and the bearings.

44. Advantages of Vertical Turret Lathe.—Heavier work can be handled on the vertical machine than on a horizontal turret lathe, especially heavy castings of irregular outline. The two turret heads permit a number and variety of cutting tools to be brought in position for simultaneous turning, facing or boring operations without interfering with each other. The main head is usually mounted on a graduated swivel base as a convenience for taper boring or turning.

SPECIAL APPLICATIONS OF TURRETS

45. Turret Applied to Engine Lathe.—Turrets are in some cases applied to engine lathes for chucking operations and

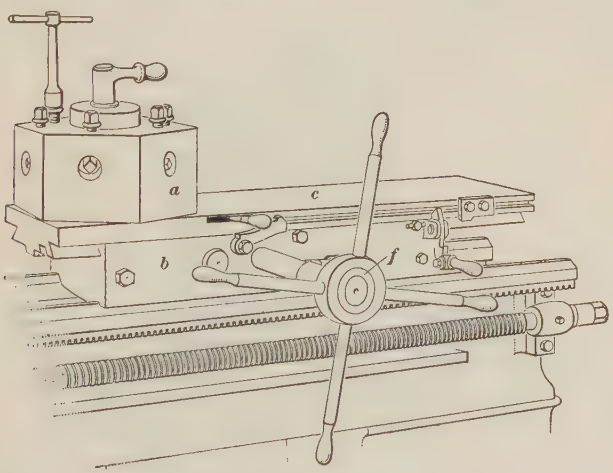


FIG. 22

for machining parts that permit the use of a regular lathe tool in the compound rest operating at the same time with one of the turret tools. Instead of changing the tools in the tool post each time it is used for boring and reaming, by the use of the turret each tool can be kept in its place and much time saved.

46. An illustration of a turret applied to an engine lathe is seen in Fig. 22. The turret *a* takes the place of the tail-stock and is provided with a bottom slide *b* that bears on the **V**'s of

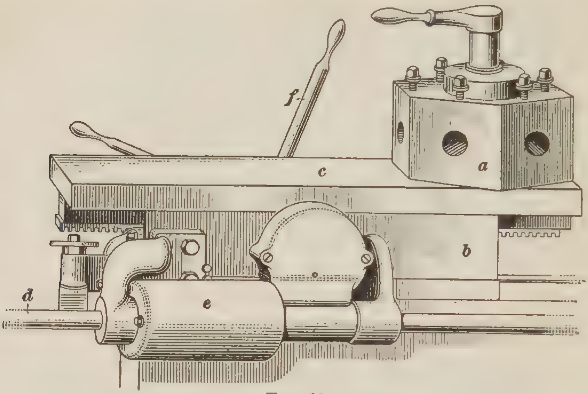


FIG. 23

the lathe and can be clamped in any position to the bed. The top slide *c* carrying the turret moves in the top of the base *b*. When the slide *c* is to be moved by power, the drive is from a

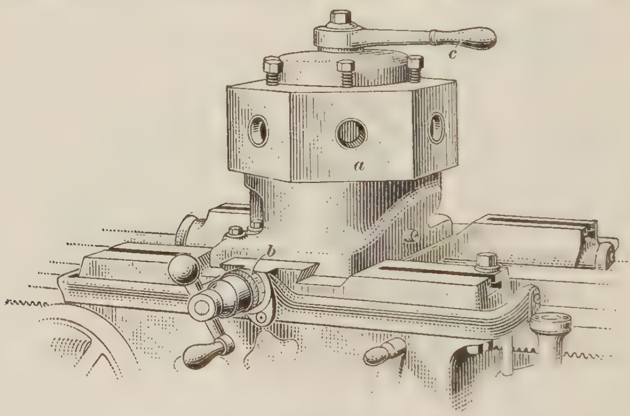


FIG 24

feed-rod *d* at the back of the lathe, as shown in Fig. 23. The feed-box *e* furnishes several changes of feed. Stops are usually provided, one for each tool, for disengaging the power feed. The hand feed is operated by a pilot wheel *f* at the front of the lathe.

47. Turret Mounted on Carriage of Engine Lathe.—A turret *a* interchangeable with the compound rest of the lathe is shown in Fig. 24. The regular graduated stop *b* and the cross-feed screw is used to locate the turret central with the lathe spindle. The power cross-feed and lengthwise feed may be applied to the turret. By using the lead screw, threading can be done by holding taps in the turret. The pitch of the taps must conform with the threads that would be cut by the regular lathe tool. The turret is indexed by hand, and locked in position by a quarter turn of the binder lever *c*.

TURRET TOOL POSTS

48. Four-Tool Turret Tool Posts.—Turret tool posts are often applied to engine lathes in place of the regular tool post. They save time where the work requires the use of several

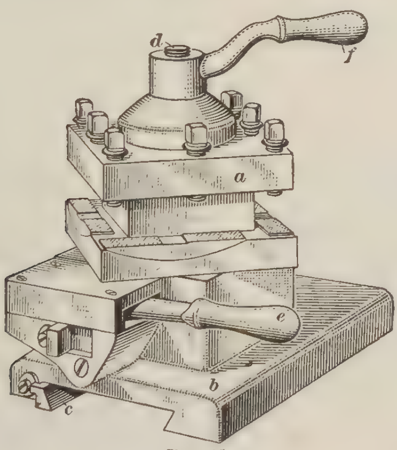


Fig. 25

tools. In Fig. 25 is shown a turret tool post *a* for four tools. The base *b* is fitted to the lathe dovetailed cross-slide, and the wear is taken up by an adjustable taper gib *c*.

49. The turret revolves on an adjustable tapered bearing about the stud *d* and a spring-operated locking pin in the base indexes the turret in its four positions. The pin is withdrawn

by the lever *e* when the turret is to be indexed, and the turret is clamped by the lever *f* threaded on the stud *d*.

50. Interchangeable-Ring Tool Post.—In the turret tool post shown in Fig. 26, an interchangeable turret ring *a*, made

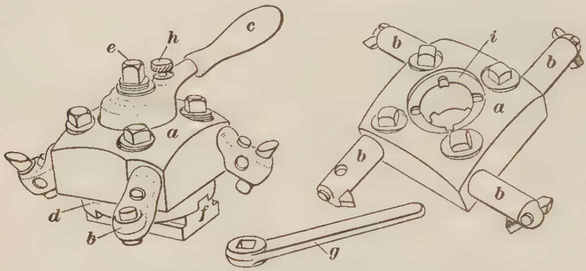


Fig. 26

of hardened steel, carries four tool holders *b*. Additional rings carrying a variety of tool combinations may be kept in readiness for successive operations on the work. The turret ring *a* is clamped to the base *d* by the lever *c* threaded on the

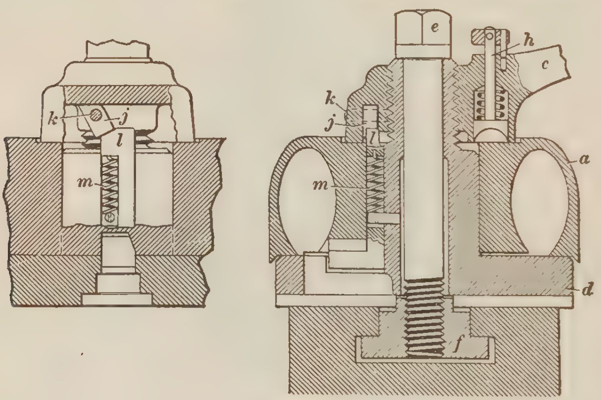


Fig. 27

stud *e*. This stud is set into the cross-slide *f* by a wrench *g*. A pin *h* enters one of the notches *i* in the ring *a*.

51. A cross-section of the indexing and locking mechanism is shown in Fig. 27. When the tool post is to be indexed to the next position, pin *h* is withdrawn and the lever *c* is

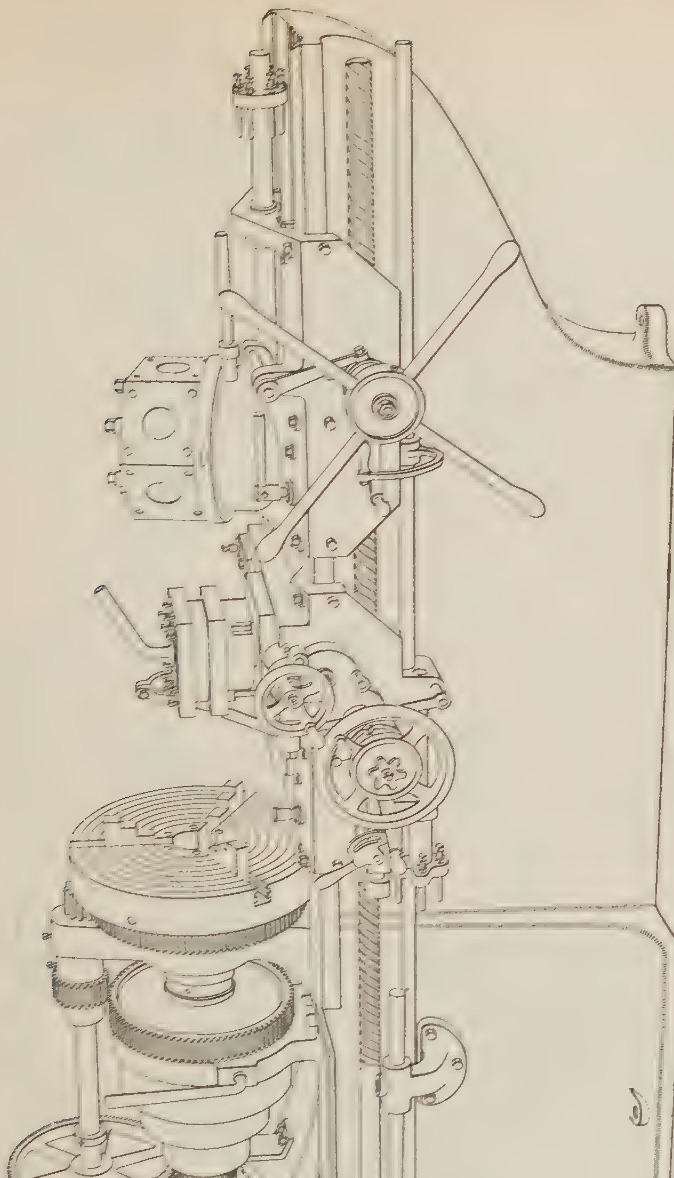


Fig. 28

unscrewed. This releases the clamping pressure and causes a pawl *j* pivoted to the lever casting by the pin *k* to engage the beveled upper side of the locking slide *l*, pushing it downwards against the action of a spring *m* and unlocking the turret ring *a*. At the same time the ratchet pin *h* engages one of the four slots *i*, Fig. 26, in the top of the turret ring, and advances the ring to the next position until the pawl *j*, Fig. 27, has passed the slide *l*, allowing it to lock the turret again. If it is desired to skip one or two of the positions, the movement of the lever is stopped at a point where the locking slide *l* is disengaged and the turret rotated by hand. The turret ring can be lifted off and replaced by another carrying different tools by lifting the pin *h* to an inactive position and unscrewing the lever *c*.

HEAVY CHUCKING TURRET LATHE

52. A chucking lathe designed for the heaviest work is shown in Fig. 28. It will not pay to install one of these machines unless a considerable number of pieces of the same design are to be made.

When it is necessary to hold long boring bars, reamers, etc., in the turret, these will interfere with the spokes of the pilot wheel, unless the turret is tilted back at an angle to the bed of the lathe, as shown.

DOUBLE-SPINDLE TURRET LATHE

53. General Features of Double-Spindle Turret Lathe. The double-spindle turret lathe shown in Fig. 29 operates at the same time on two similar pieces of either rod or chuck work. The special features of this lathe are its two similar hollow spindles driven at the same speed, a cross-sliding headstock for facing and tapering operations, and a square flat turret with a duplicate set of cutting tools on each face.

54. Details of Double-Spindle Cross-Sliding Head.—In Fig. 30 is shown the arrangement of the chucking end of the double-spindle headstock, and in Fig. 31 is shown its belted or driving end. A helical gear is bolted to a flange on the end

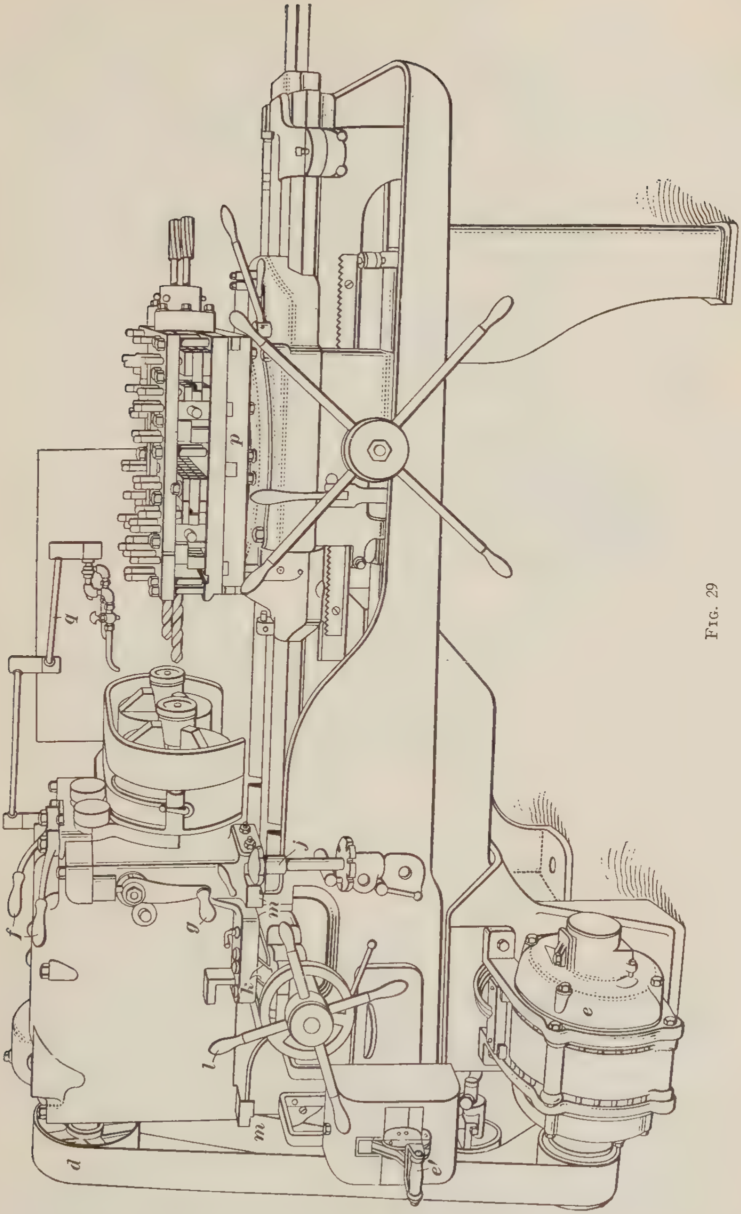


Fig. 29

of each spindle *a* and *b*, Fig. 30, and both spindles are driven by a centrally located pinion *c*.

A pulley *d*, Fig. 31, is driven at constant speed from a motor *e* located either as in Fig. 29 or as in Fig. 31. The

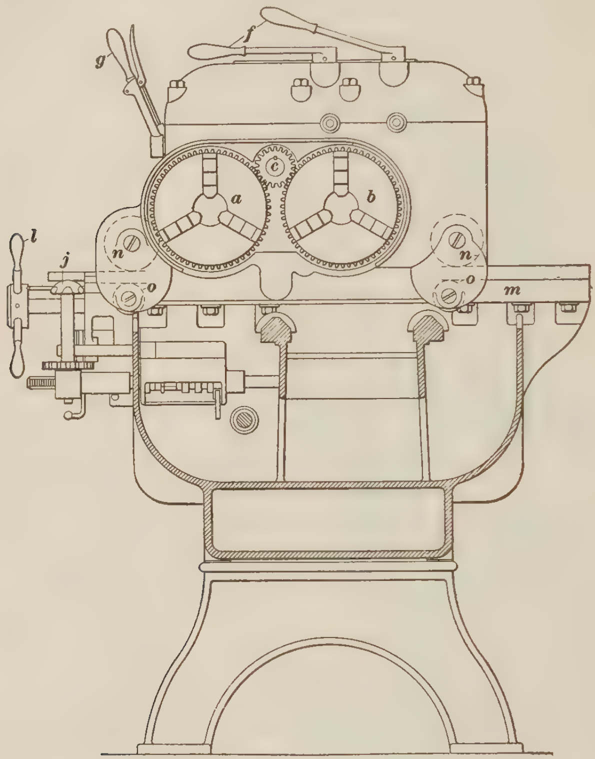


Fig. 30

motor control-box handle is shown at *e'*. Between the drive shaft with its pulley *d* and the shaft of pinion *c* there are two intermediate shafts fitted with change gears and clutches. These clutches are operated by the two handles *f* on the top of the case, whereby the spindles *a* and *b* may be driven at nine different speeds either forwards or in reverse. The reverse lever is shown at *g*.

The rear end of the spindle *b*, Fig. 31, has a pulley that drives the pulley *h* on the quick-change gear-box *i* in the base

of the head. The gear-box is arranged to give nine different power feeds to both the turret and the cross-movement of the headstock. These feeds are controlled by the handle *j*; the changes may be made during the cut, and the headstock and the turret feeds are independent of each other. A set *k*, Fig. 29, of nine fine-adjustment stops located back of the pilot wheel *l* gauges the cross-movements of the head, and a stop is

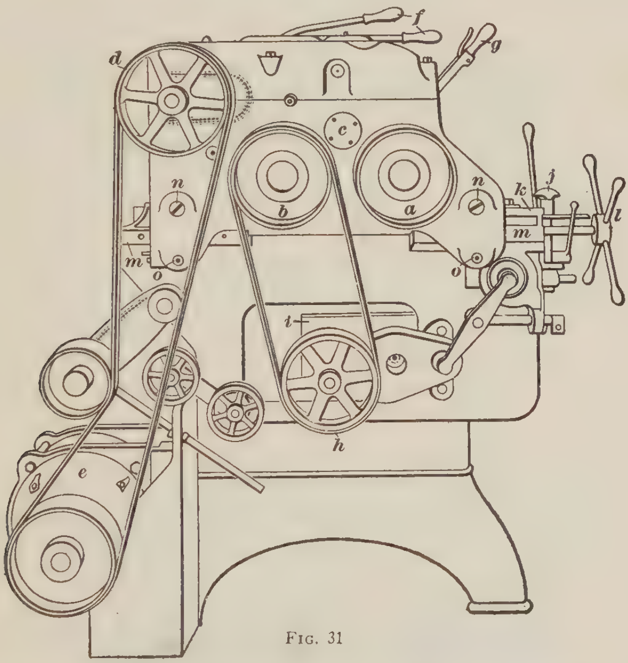


FIG. 31

also used to line the spindles with the bored tool holders in the turret. The bearings and gears in the tightly enclosed headstock are oiled by a pump and a revolving spray distributor. The headstock may be moved back and forth across the bed, as it is located on guides *m*, at each end, Figs. 30 and 31. Two small rollers *n* on each end of the headstock carry its weight as they roll on the top of the guides, and two rollers *o* are in contact with the under surface of the guides and prevent any upward movement of the headstock.

A single piece of extra large work can be turned by using only one spindle with a large chuck or face plate, the two smaller chucks being removed. For rod work the scroll chucks must be replaced with collet chucks having operating levers.

55. Details of Flat Turret on Double-Spindle Lathe.—The turret, Fig. 29, consists of a square flat plate *p*, with two pairs of grooves at right angles across its top for lining up the duplicate sets of tool holders with the two spindles. The tools and tool holders are bolted to the top of the plate as shown. Also, there is a short groove at each corner of the turret which permits tool holders to be located at these points, and there are short grooves at the middle of each side of the plate. It is an advantage to have the tool holders located on the corners of the plate for inside operations on a single piece. The indexing is for the four sides of the turret together with its four corners, making eight positions in all. There are six stops that work in both directions for each tool. The lubrication may be applied to the cutting tools either directly as shown at *q*, or the oil may be fed through tubing into the hollow tool holders.

SMALL TYPES OF TURRET LATHES

56. Jeweler's or Watchmaker's Turret Lathe.—The smallest type of turret lathe is known as the jeweler's or watch-

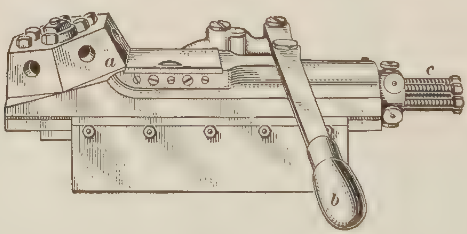


FIG. 32

maker's lathe. This lathe is usually mounted on a bench. It is adapted to the production of a great variety of small work that may be held in a chuck or on a face plate, or which may be machined from the end of a rod. These lathes

are used where exceptional accuracy is required such as for optical work, watch and clock work, small tools, etc.

57. Turret of Jeweler's Lathe.—The turret *a*, Fig. 32, has holes for six tools. It is set at an angle of inclination of 15°

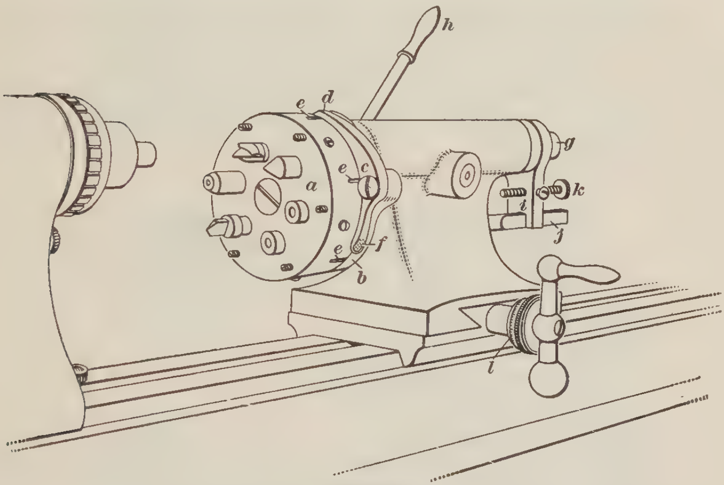


Fig. 33

with the horizontal so as to get a low and rigid construction. It is indexed and given its stroke by means of the hand lever *b*. There is a set of six stops *c*, one for each tool in the turret.

58. Tailstock Turret.—A six-tool tailstock turret is shown in Fig. 33. The tapered holes in the turret *a* are made to receive the shanks of standard tools. The turret is mounted on a plate *b* so that it may be revolved and indexed to locate each tool in line with the lathe spindle center. The indexing lever *c* is fitted on a lug on the edge of the plate *b*, and the end *d* of this lever is held by a spring in one of the six notches *e* in the circumference of the turret. By pressing on the end *f* of the lever the turret is made free and can be revolved by hand to the next position.

The turret plate *b* has a tapered shank that fits in the tailstock spindle *g*, which is operated by a spiral rack and pinion by the hand lever *h*. A bar *i* is attached to the spindle *g* and

is slotted to slide along the guide *j*. A stop-screw *k* limits the endwise movement of the spindle and the action of the tool. In place of the single stop *k* a set of six stops may be used. The tailstock is mounted on a cross-slide and its set-over may be measured by the micrometer dial *l* on the feed-screw.

59. Half-Open Tailstock.—A turret carrying a single tool at one time is embodied in the *half-open* tailstock shown in Fig. 34. This tailstock consists of a two-pedestal base *a* that can be bolted to the bed of a bench lathe. The bearings *b* consist of the under half only, so that the spindle *c* may be dropped

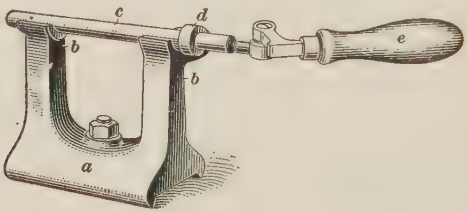


Fig. 34

into the bearings or removed from them instantly. The spindle is fitted with an adjustable stop-collar *d* that regulates the endwise movement of the spindle by the lever *e*. There is a taper hole in the inner end of the spindle to receive the shanks of standard tools. Several spindles are usually furnished so that each tool of the series used on any piece of work can be set in a separate spindle. As very rapid changes of spindles can be made it is possible to turn out work with this style of turret very quickly.

AUTOMATIC THREADING TOOLS

60. Purpose of Automatic Threading Tools.—There are numerous makes of taps and dies that release themselves automatically from the threads they cut. This feature greatly increases the rate of cutting threads, and also saves the threads from the risk of injury that is common to the backing-out or backing-off method required by the solid threading tools. These automatic tools are usually made so that they can be adjusted to cut the threads either slightly large or small, and

they may be used to cut either right- or left-handed threads; also each tool threads a moderate range of different sizes, and some may be adapted to threading tapered work. Furthermore, the chasers for threads of different forms may be used in the same tap or die head. Two of the desirable features of automatic threading tools are that the chasers can be very easily removed and that they may be ground readily in sets.

One class of automatic threading tool is designed to revolve and thread work that is held stationary. In the other class the tool is held stationary in the turret or tool post and the work

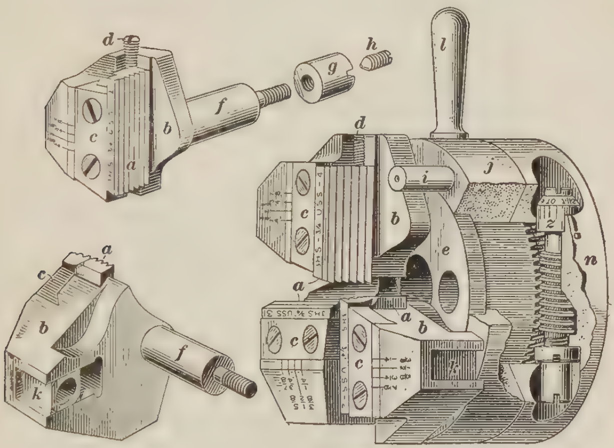


FIG. 35

revolves. The examples of automatic threading tools described in this Section are selected from the many stationary types.

61. Tangential Chaser Automatic Die Head.—The automatic die head shown in Figs. 35 and 36 is of the stationary, or non-rotary, type as adapted to turret lathes and screw machines. The chasers *a*, Fig. 35, are cut over the entire flat side and they act endwise, or tangential, when threading the work. This form of chaser is sharpened by grinding across its end. The chasers are attached to their holders *b* by a clamp *c*, which has a screw *d* to give the chaser a proper adjustment lengthwise. The chaser holder *b* is held against the face of the die body *e* by trunnions, or extensions, *f* that pass through

the body and have a nut *g* and a lock-screw *h*. The opening and the closing of the die are caused by swinging the chaser holders *b* and their trunnions *f* in the body *e*. The swinging is done by pins *i* on the closing ring *j*, engaging the sliding blocks *k* set in the back part of the holders. When the closing ring *j* is moved by the handle *l*, the chasers swing to the closed position and they are locked by the mechanism shown in Fig. 36. When the turret movement is halted and a pull-back is given to the chasers on the threads, lock-pins a_1, release the ring *j*; and the coiled spring *m* in the ring *n*, Fig. 36, acting on the flat pin *o* revolves the ring *j* backwards and opens the chasers.

62. Details of Tangential Chaser, Automatic Die Head. The details of the assembled die head, Fig. 35, are shown in Fig. 36, together with the hollow shank *p* and the zero plate *q*. The body *e* passes through the rings *j* and *n*, as shown in Fig. 35, and the bore *r*, Fig. 36, of the zero plate *q* fits over the part *s* of the body. Furthermore, the central projection *t* of the body *e* bears through the hole of the zero plate *q* and in the hole *u* of the shank *p*. The zero plate *q* is fastened to the body *e* by four screws *v*, which bind together and make a combination unit of the parts *e*, *j*, *n*, and *q*. When these parts are being assembled, the small pin *w* on the body *e* should enter a hole (not shown) in the end, or cover, of the zero plate *q*, the purpose of this method being to locate all the parts in their proper relation to each other.

63. The coiled spring *m*, Fig. 36, in the ring *n* is held in compression against the side of the flat pin *o* of the ring *j* by means of a hollow screw plug *x*, the purpose of this form of plug being to permit the use of a long spring *m* in a short space. A solid screw plug *y* is used to close the opposite end of the hole to keep out dirt, chips, etc. When left-hand threading is to be done, the locations of the screw plugs *x* and *y* are reversed. A worm *z* with a dial-head is mounted in the ring *n*, and is used to revolve the body *e* together with the zero plate *q*. By this arrangement it is possible to make an adjust-

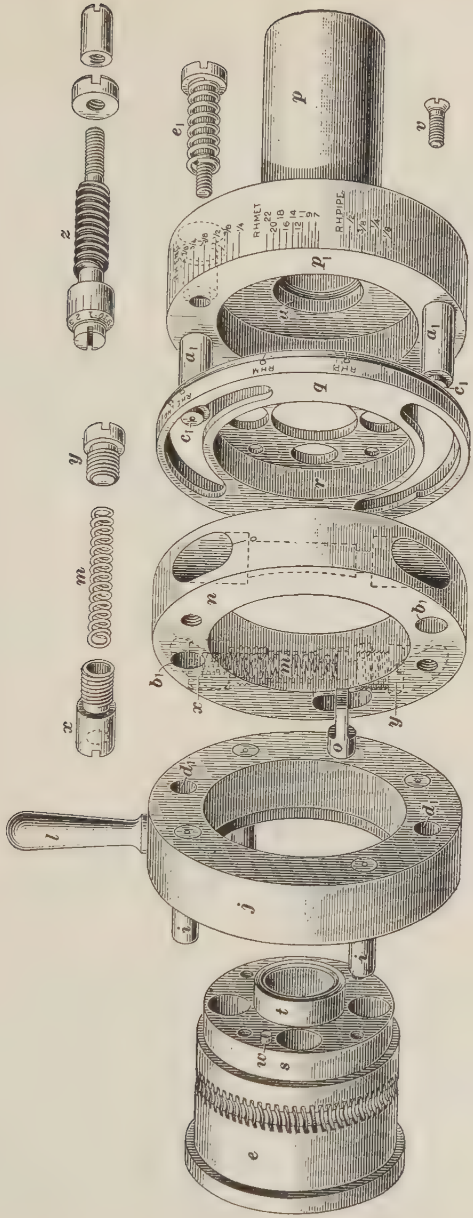


Fig. 36

ment of .005 inch in the diameter of the thread, thus cutting either a loose or a tight-fitting thread as may be required.

The large end of the shank p has graduations on its circumference, which are used to set the die to size for cutting right-hand pipe threads on from $\frac{1}{8}$-inch to $\frac{1}{2}$-inch pipes, right-hand metric threads from 7 to 22 millimeters in diameter, right-hand English threads on pipes from $\frac{1}{4}$-inch to $\frac{7}{8}$-inch diameter, and left-hand English threads. There is a corresponding zero mark on the edge of the zero plate for each of these scales.

64. The shank p, Fig. 36, has two driving pins a_1 that pass through long circular slots in the zero plate q and have a sliding fit in the two holes b_1 through the ring n. The small extensions c_1 on the driving pins a_1 enter the two holes d_1 in the ring j and lock the rings j and n together when the chasers are closed. The shank p is attached to the ring n by two screws e_1 having coiled springs as shown. These screws and springs permit an endwise motion between the shank p and the combination parts e, j, n, and q equal to the length of the extensions c_1 on the driving pins a_1. When the shank separates from the combination parts, the extensions c_1 are withdrawn

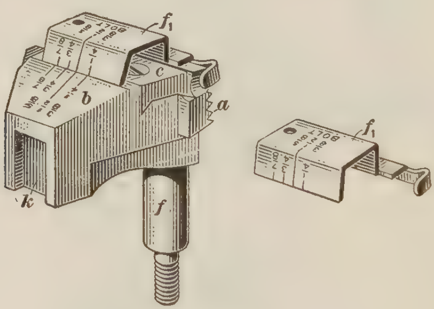


Fig. 37

from the holes d_1 and release the ring j, which revolves backwards by the action of the spring m and opens the chasers. The zero ring q is counterbored to a depth greater than c_1 and fits over the end of the shank p, so that there is no crack left uncovered between the zero ring and the surface p_1 of the shank p when the two parts separate. This covering by the

edge of the zero ring q prevents the entrance of dirt or chips.

65. To take this die head apart remove the two screws e_1, Fig. 36, which will detach the shank p. The nuts g and lock-screws h, Fig. 35, will then be exposed in the inner end of the body e, so that the chaser holders b can be removed or adjusted.

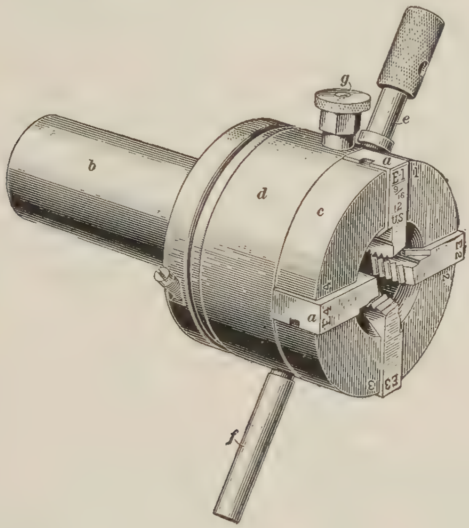


FIG. 38

The other parts can be separated by removing the screws v, Fig. 36, from the zero plate q. Screwdrivers are the only tools needed to take the die apart and to make any of its adjustments.

66. The method of setting the chasers is shown in Fig. 37. A gauge f_1 furnished with the die is used to locate the cutting end of the chasers. A scale is cut in the chaser holders and also on the gauge, as shown, and the chasers are set by the gauge so that the required dimension on the gauge coincides with the similar dimension on the holder. The illustration shows the chasers set for threading a ½-inch bolt.

67. Radial Chaser Automatic Die Head.—The die head shown in Fig. 38 has its chasers a set radially. The shank b

is held in the turret, and the work must revolve. The four chasers are threaded across their ends and slide radially in slots in the front part *c*, and act edgewise when cutting the thread. Each set of chasers is numbered from 1 to 4, and each chaser must be used in the slot having its corresponding number. The letter *E* as shown on these chasers indicates the maker's lot number as kept in his records. The *12* marked on the chasers gives the number of threads per inch, $\frac{9}{16}$ is the diameter of the threads, and *U. S.* is the form of the thread that these chasers will cut.

The chasers are closed and locked in their cutting position by turning the ring *d* by the handle *e*; also this closing may be done automatically as the turret revolves, by using the pin *f*, which comes in contact with a bar attached to the turret slide. A pin *g* is provided to unlock the chasers from the slots in the front part *c* when the chasers are to be removed for grinding or changing.

68. Details of Radial Chaser Die Head.—The various parts of the die head shown in Fig. 38, and their relation to each other are shown in Figs. 39 and 40. For the sake of clearness the same parts have the same reference letters in the different illustrations. The chasers *a* receive their radial motion from the diagonal cams *h* attached to the face of the cam-ring *d*, shown in views (*c*) and (*e*), Fig. 39, and view (*c*), Fig. 40, which is operated by a handle *e* or pin *f*. When the inner ends of the cams *h* are revolved into the notches across the backs of the chasers *a*, the chasers become closed; they are opened by revolving the outer ends of the cams into the chaser notches. The opening action of the cams is limited by the pin *g*, which projects into the short slot *i* in the hub c_1 of the front part *c*, as shown in views (*e*) and (*f*), Fig. 39, and views (*a*) and (*b*), Fig. 40. Withdrawing the pin *g* from the slot *i* leaves the cam-ring *d* free to revolve until the cams *h* pass entirely out of the chasers. When this is done the chasers may be removed from, or placed in, the head.

69. The assembly shown in view (*c*), Fig. 39, is made up of the three parts shown in views (*d*), (*e*), and (*f*), together

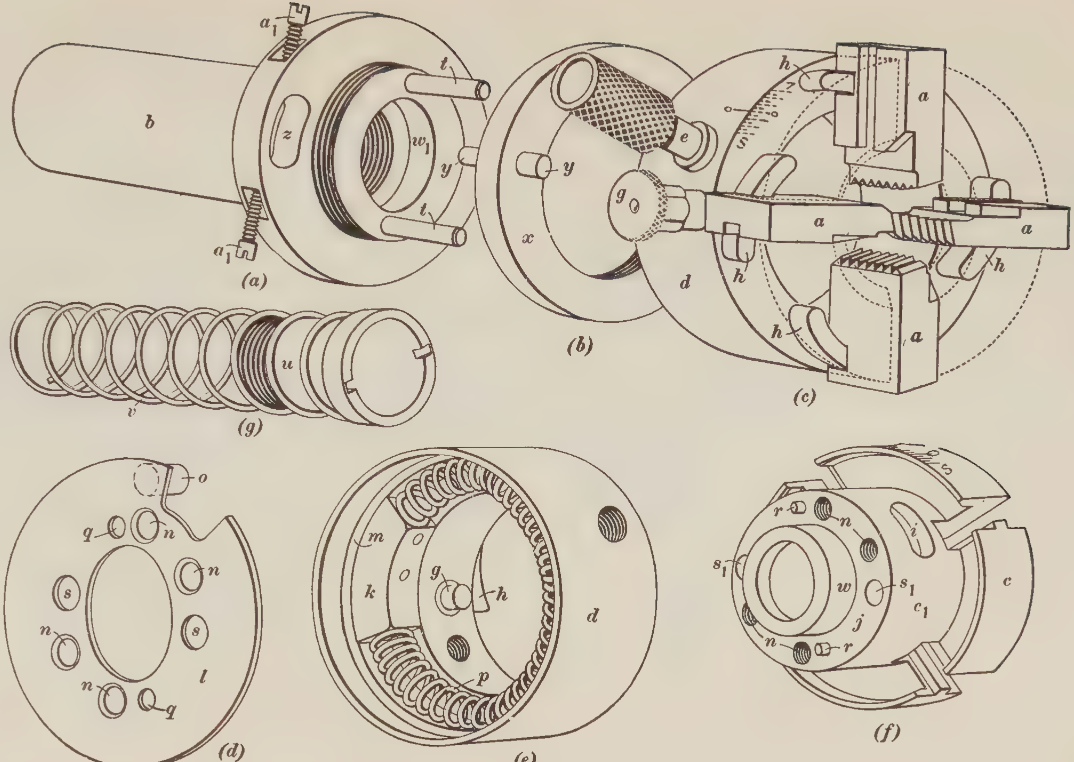


FIG. 39

with four chasers, the handle e, and the pin f. The cam-ring d fits over the hub c_1 on the back of the front part c, view (f), and is located so that the inner end of the pin g enters the slot i. The face j, view (f), of the hub comes even with the face k of the block riveted in the cam-ring d, view (e), and the cam-spring plate l, view (d), fits against the shoulder m, view (e), and the face j, view (f), and it is fastened to j by four flat-head screws j_1, Fig. 40 (a), in the holes n, Fig. 39 (d) and (f). The three parts c, d, and l are thus held firmly together endwise, with the middle, or cam-ring d, free to be revolved between c and l. The pin o projecting from the inside of the plate l, view (d), Fig. 39, and view (a), Fig. 40, extends a short distance across the end of the block k and between the block and the end of the coiled spring p, view (e), Fig. 39, and views (a) and (b), Fig. 40.

70. The spring p, Fig. 39 (e), is compressed by the pin o, view (d), when the ring d is revolved by the handle e, view (c). The three parts shown in views (d), (e), and (f), are assembled properly when the two holes q in the plate l fit over the pins r on the face of j, view (f). The two larger holes s in the plate l then register with the two holes s_1 in the face j and receive the two driving pins t from the face of the shank b, Fig. 39 (a) and 40 (a). These driving pins withstand the thrust of the cutting action of the chasers and transmit it to the grip of the shank b in the turret.

71. The threaded sleeve u, Fig. 39 (g), and Fig. 40 (b), with its spring v, is inserted through the front of the part c, Fig. 39, and screwed into the end of the shank b, thus holding the front part assembly and the shank b together. The projection w, in view (f), and Fig. 40 (b), enters the counterbore w_1 in the shank b, Fig. 39 (a), and forms a bearing between the parts shown in views (a) and (c), Fig. 39. The use of the spring v, Fig. 39 (g), allows a slight endwise movement between the parts shown in views (a) and (c). The purpose of this endwise movement is to operate the locking mechanism that holds the chasers closed and also automatically opens them.

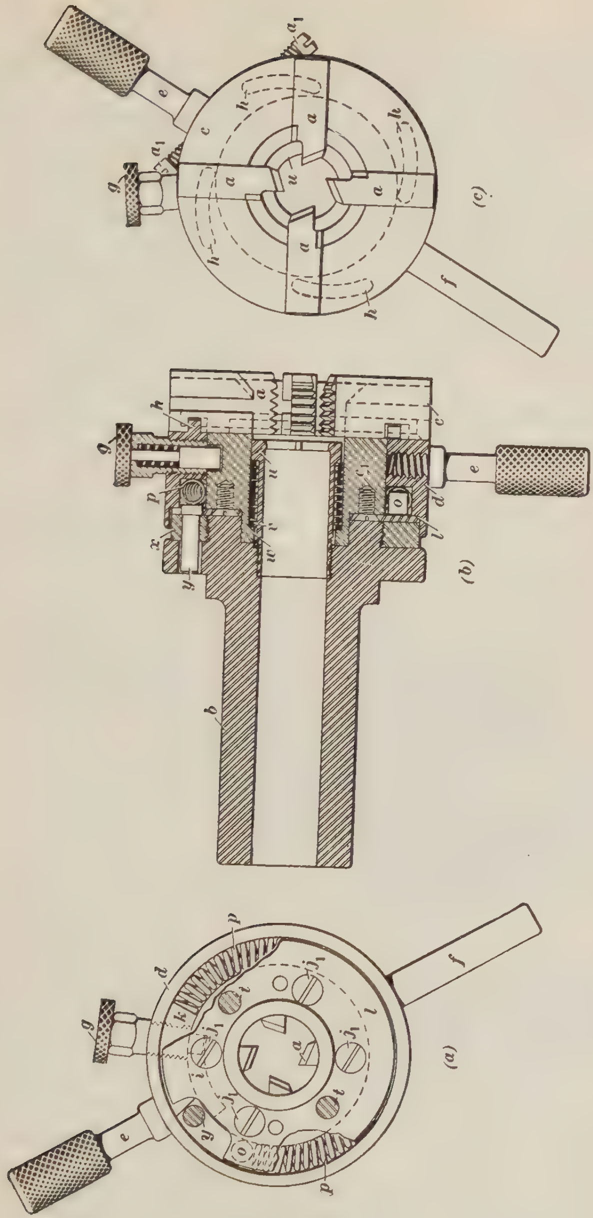


Fig. 40

72. The adjusting ring *x*, Fig. 39 (*b*), is screwed on the shank *b* and the lock-pin *y* is driven tightly into it. The outer end of this pin extends through the slot *z*, view (*a*), and between the two screws a_1. The purpose of the two adjusting screws a_1 is to set the locking-pin *y* either forwards or backwards along the circumference, and thus regulate the distance that the cam-ring *d* must move in order to reach the locking position. The normal locking position that sets the chasers to thread the standard diameter of thread is when the zero lines of the scale *S-L* coincide, Fig. 39 (*c*) and (*f*). When the lock-pin *y* is set so that its locking position is toward *S*, the thread will be cut small; when the position is toward *L*, the thread will be cut large.

73. The inner end of the lock-pin *y*, Fig. 39 (*b*), extends through the notch cut into the edge of the plate *l*, view (*d*), and against the surface *k* of the cam-ring *d*, Fig. 39 (*e*), and view (*a*), Fig. 40. When the ring *d* is revolved by the handle *e* and the chasers are brought to their closed position, the end of the lock-pin *y* just clears the end of the block *k* and the tension of the spring *v*, view (*g*), Fig. 39, and view (*b*), Fig. 40, draws the parts shown in (*a*) and (*c*) close together. This forces the end of the lock-pin *y* into the cavity at the end of the block *k* and thus locks the cam-ring *d* so that it cannot revolve backwards when the hand is removed from the handle *e*. It will be seen in Fig. 40 (*a*) that the pin *o* has moved the end of the spring *p* a considerable distance from the end of the block *k*, and leaves all the clearance space required for the lock-pin *y* to enter. After the chasers finish their cut, a slight endwise movement will separate the part shown in (*a*) from the part shown in (*c*), Fig. 39, and draw the lock-pin *y* from the end of the block *k*. Then the spring *p* is free to revolve the cam-ring *d* backwards and open the chasers. The pull for separating the parts shown in views (*a*) from (*c*) may be given either by halting the travel of the turret by hand or by the use of a stop.

74. In Fig. 40 (*b*) is shown how the cam-ring *d* overlaps the adjusting ring *x* enough to allow a separation of from

$\frac{1}{16}$ inch to $\frac{1}{8}$ inch between x and d, and still keep the space between the faces of these two parts covered. This prevents chips or dirt from entering the head.

In Fig. 40 (b) is shown a sectional view of the internal arrangement of the parts when assembled. However, this view is *conventional* because some of the parts, such as the handle e, the compression pin o, the spring p, the lock-pin y, and the adjusting ring x are shown revolved into the plane through which the section is taken, and not in their true relationship to each other as in views (a) and (c).

75. To take the die head apart, hold the shank b, Fig. 39 (a), in the turret or vise, lift the pin g, Fig. 40 (b),

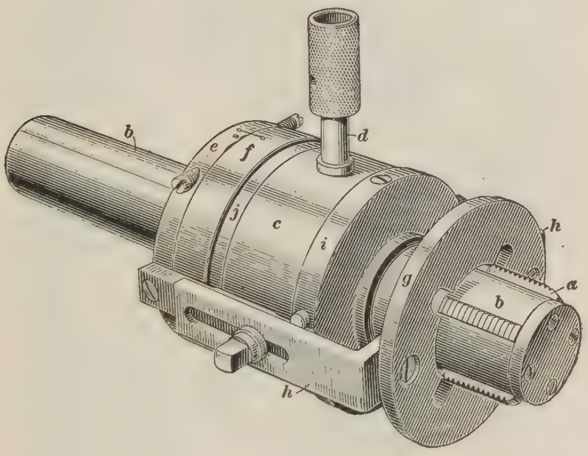


FIG. 41

and remove the chasers. Then take out the sleeve screw u and spring v, Fig. 39 (g), and Fig. 40 (b), which will allow the parts (a) and (c), Fig. 39, to be separated. To separate the part shown in Fig. 39 (c), take out the four screws j_1, Fig. 40 (a), that hold the plates l and c.

76. Collapsing Tap.—One make of collapsing tap of the cam-operated type is shown in Fig. 41. The four chasers a are moved in or out radially in slots cut in the end of the hollow body b. The chasers are moved outwards by revolving a

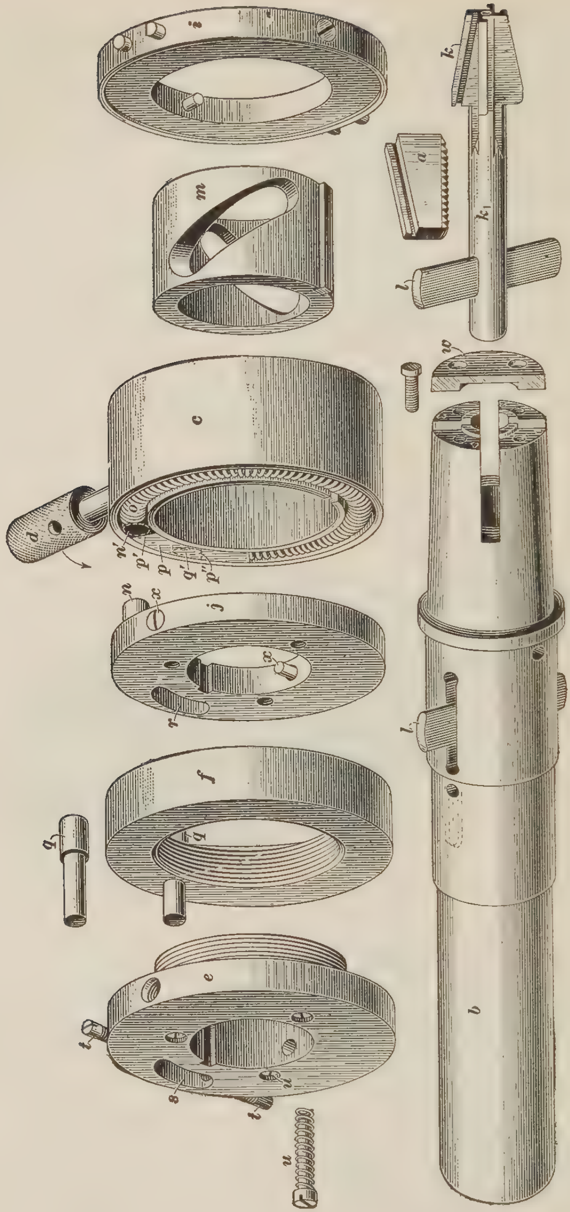


Fig. 42

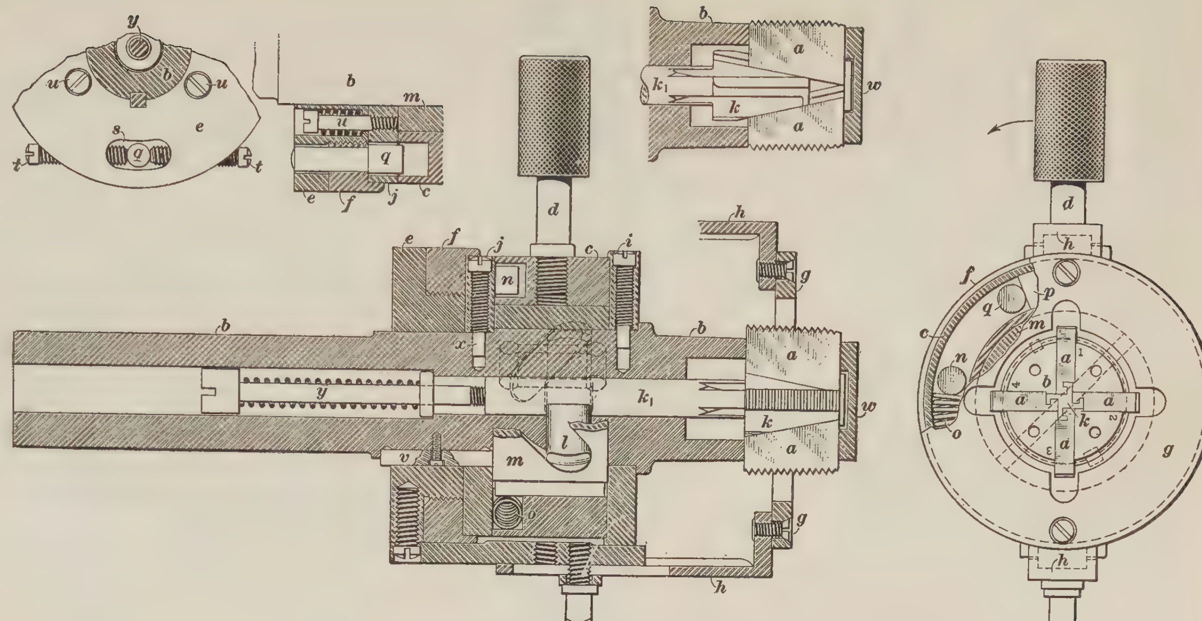


FIG. 43

ring, or cam-sleeve, *c* by means of the handle *d*. The *in*, or collapsing movement, is given by a coiled spring in the cam-sleeve *c*. The inside mechanism and adjustments are shown in Figs. 42, 43, and 44. The chasers may be set to cut either large or small by means of an adjustment between the back part *e* and the back-part ring *f*, as indicated by the letters *L* and *S* shown on the scale.

77. The collapse of the chasers is caused by holding back the turret when the required length of thread has been cut. The hold-back may be by hand, or by an automatic trip

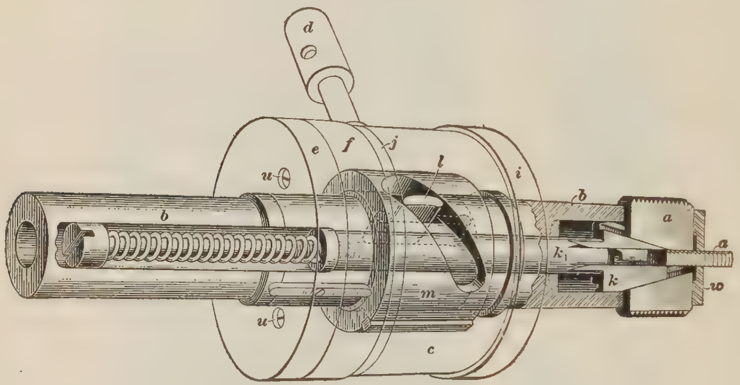


FIG. 44

as follows: A slotted plate *g*, Fig. 41, is set over the chasers *a*, and it has two supporting arms *h* that are attached to the back part *e*. The adjustment in the length of the arms *h* allows the plate *g* to be located at any point along the chasers as the length of the thread in the work may require. When the plate *g* strikes the end of the work, the plate moves backwards slightly and transmits this motion by the arms *h* to the back part *e*. This motion pulls the locking pin from the cam-sleeve *c* and permits a coiled spring within the sleeve to revolve it backwards and quickly collapse the chasers. The front plate *i* and the back plate *j* are both attached to the body *b* by two long screws, and these plates keep the cam-sleeve *c* from moving sidewise from its position on the body *b*.

78. Details of Collapsing Tap.—The details and adjustments of the collapsing tap, Fig. 41, are shown in Figs. 42, 43, and 44. The four chasers *a* are attached to and slide in the grooves of the tapered wings *k* on the outer end of the plunger k_1. When this plunger moves outwards the chasers are expanded, and its inward movement collapses the chasers. The plunger k_1 is moved lengthwise of the body *b* by the flat key *l* that extends clear through the plunger, the body, and the cam-ring *m*. The cam-ring is keyed to the sleeve *c*, so that the movement of the sleeve by the handle *d* or the spring *o*, as explained above, operates the plunger and the chasers.

79. The back plate *j*, Figs. 42 and 43, is fixed to the body *b* by a key and the pins *x*. It has a heavy pin *n* on its inner side, and this pin projects into the groove of the cam-sleeve *c*, as shown at *n′*, at the end of the coiled spring *o*. When the cam-sleeve *c* is revolved by the handle *d* in the direction of the arrow to expand the chasers, the pin *n*, remains stationary while the edge *p′* of the block *p* is moved around to the position *p″*, and compresses the spring *o*. The block *p* attached to *c* is thus moved from under the inner end of the lock-pin *q* in the back-part ring *f*, and this pin drops into the empty groove in the position shown by the dotted circle *q′*. See also the positions of the pin *u*, block *p*, and pin *q*, in Fig. 43, which shows the tap set in the expanded and locked position. The lock-pin *q* prevents the cam-sleeve *c* from reversing its motion when the hand is removed from the handle *d*. Thus the chasers are expanded by the hand-lever movement and are also locked in the position ready to thread the work. When the lock-pin *q*, Figs. 42 and 43, is withdrawn from the groove by the action of the trip *g*, moving the back parts *e* and *f* away from the cam-sleeve *c*, Fig. 41, the coiled spring *o* is free to force the cam-sleeve *c* to revolve with its cam-ring *m* and pull the plunger k_1 backwards and collapse the chasers. The block *p* is attached to the cam-sleeve *c* and moves back to its starting position shown in Fig. 42, and the end of the lock-pin *q* will then rest on the surface of the block *p*, as shown by the dotted circle *q′*.

80. The lock-pin *q*, Fig. 42, is attached to the back-part ring *f*, and its inner end projects through the slot *r* in the back plate *j*. The outer end of the lock-pin projects through the slot *s* in the back part *e* and between the two setscrews *t*. By means of these screws the lock-pin with the back-part ring *f* may be shifted slightly in relation to the back part *e*, and the amount of this shift is shown on the micrometer scale *L-S*, Fig. 39. This adjustment changes the distance that the cam-sleeve *c* must revolve in order to move the block *p* from under the lock-pin *q*, and thus varies the amount that the chasers are expanded.

81. The combination of the back part *e* and the back-part ring *f*, Fig. 42, is attached to the fixed plate *j* by three long screws *u*. Each screw has a coiled spring, as shown, that tends to hold the back part *e* and the ring *f* against the plate *j* and at the same time permits a short end play of the back part *e* and back-part ring *f* along the key *v*, Fig. 43. This back play is made use of by the trip. Thus, the trip moves the back part *e* and the back-part ring *f* backwards against the pressure of the springs on the three screws *u* until the end of the locking pin *q* is withdrawn from the groove in the sleeve *c*, and clears the end of the block *p*, which permits the sleeve *c* to revolve backwards in the direction of the arrow, Fig. 43, till the block *p* strikes the stationary pin *n*, Fig. 42, and collapses the chasers. On the other hand, when the sleeve *c* is revolved by the handle *d* in the direction of the arrow, Fig. 42, to expand the chasers to the locking position, the action of the springs on the screws *u* forces the back part *e*, the back-part ring *f*, and the plate *j* together and the locking-pin *q* into the space formed between the end of the block *p* and the pin *n*, Fig. 43.

82. It will be noted that part *f*, Fig. 42, is counterbored and fits over the fixed plate *j*, as shown in Fig. 43. This counterbore is deep enough to prevent uncovering the space between the back part *f* and the plate *j* when they are farthest apart by the action of the trip. The purpose of this overlap is to prevent dirt or chips from entering the space between part *f* and plate *j*.

83. Taking Collapsible Tap Apart.—To remove the chasers take off the cap plate *w*, Fig. 42. The chasers are numbered from 1 to 4 and must be located in the slots having corresponding numbers. To inspect, clean, and oil the inside of the tap, remove the three screws *u* and slide off the part *e* and the ring *f*. Take the two long screws *x*, Figs. 42 and 43, from the fixed plate *j* and this plate and the sleeve *c* will be free to come off. Then the flat key *l* may be pushed out to free the plunger k_1, except that the long screw *y* must be withdrawn before the plunger can be taken from the body *b*. The purpose of the long screw *y* and its coiled spring is to take up any loose end play of the plunger and cause the chasers to collapse fully each time. To remove the cam-ring *m* take the key *v* from the body *b*. A wrench and a screwdriver are needed to make the adjustments.

TURRET LATHE PRACTICE

TOOLS AND OPERATIONS

TOOLS

SMALL TURRET TOOLS

1. Drills.—Small turret tools, such as drills, reamers, and counterbores, may be held either in the turret, in chucks, or in tool holders provided with taper or straight-hole bushings to fit the shanks of the tools. In Fig. 1 is shown a short two-lip starting drill with a straight shank. A deep holder for a long bushing is used to hold the drill. These bushings are interchangeable and are held in place by screws.

FIG. 1

2. Counterbores.—Counterbores are tools for enlarging the entrance of a straight hole that has already been drilled, and facing the bottom of the enlarged part at the same time. Their shanks are made either tapered or straight and are inserted in tool holders with interchangeable bushings. Small counterbores for turret lathes are the same as those described for use with drilling machines.

3. Reamers.—The function of a reamer is not that of a boring tool, to remove stock, but to clear up a hole that has already been bored. When too much stock is left for the reamer to remove, the tool may become clogged and the hole will not be true. Practical allowances for stock to be removed by reaming are as follows: Cast iron, .002 inch to .005 inch; brass, .003 inch to .006 inch; steel, .002 inch to .003 inch. Reamers should be kept sharp and true to do accurate work. When a reamer becomes dull, the cutting edge can be honed a few times if care is taken to preserve the clearance angle of the tool. If the reamer becomes too dull it should be reground on a universal grinder and the teeth backed off to obtain the necessary clearance.

4. Classification of Reamers.—Reamers may, in accordance with their shape, be divided into three general classes. These are *straight reamers, taper reamers*, and *formed reamers*. Each of these classes may be divided into three subclasses, according to their construction. These are *solid reamers, inserted-blade reamers,* and *adjustable reamers*.

Formed reamers are used for reaming holes that are neither straight nor tapering and usually require special machines for their production and grinding. They are rarely used, as their first cost is considerable and they are very hard to duplicate.

5. Solid Reamers.—Solid reamers for reaming straight holes may have either straight or helical cutting edges and may be made with straight or taper shanks to fit the tool holders in the turret. Straight reamers that are intended to cut at their ends only, like rose reamers and chucking reamers, are made of uniform diameter throughout their length, since the part back of the cutting edge serves as a guide. Straight reamers that have their cutting edges along their whole length require the front end to be slightly chamfered in order that they may enter the hole easily.

6. Inserted-Blade Shell Reamers.—Inserted-blade shell reamers are in general use on turret lathes because they can be readily restored to their original size when worn. The worn

blades are removed and a strip of paper or tinfoil is laid on the bottom of each cavity; the blades are then put back in place and ground on centers.

7. Both right-hand and left-hand helical inserted-blade reamers are used. For fast reaming in steel, right-hand helical reamers are used. Left-hand helical reamers are used for fine finish in steel, aluminum, and bronze. Straight-blade reamers are used for machining cast iron. There is very little trouble from the chips when helical cutting edges are used, as the chips will work out along the flutes.

8. Solid Taper Reamers.—Holes that taper only slightly are first bored straight and then reamed with a taper reamer; for very abrupt tapers the reamer should be preceded by a boring bar having two or more cutters, as shown in Fig. 2.

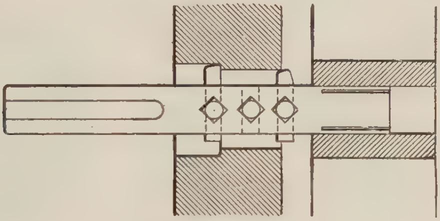


Fig. 2

These cutters make stepped holes of approximately the size of the desired taper hole, and remove most of the stock. The steps are then removed with a taper roughing reamer followed by a finishing reamer.

For reaming holes with only slight taper, roughing reamers may have either straight flutes or slight left-hand spiral flutes, to prevent the reamer from pulling into the hole and causing chatter. For holes that taper considerably, the reamers can be made with a right-hand spiral. Finishing reamers are usually made with straight flutes or with a left-hand spiral, and they may have more flutes than the roughing reamers.

9. Adjustable-Cutter Boring Bar.—Boring-bar cutters should be capable of convenient adjustment; also, they should

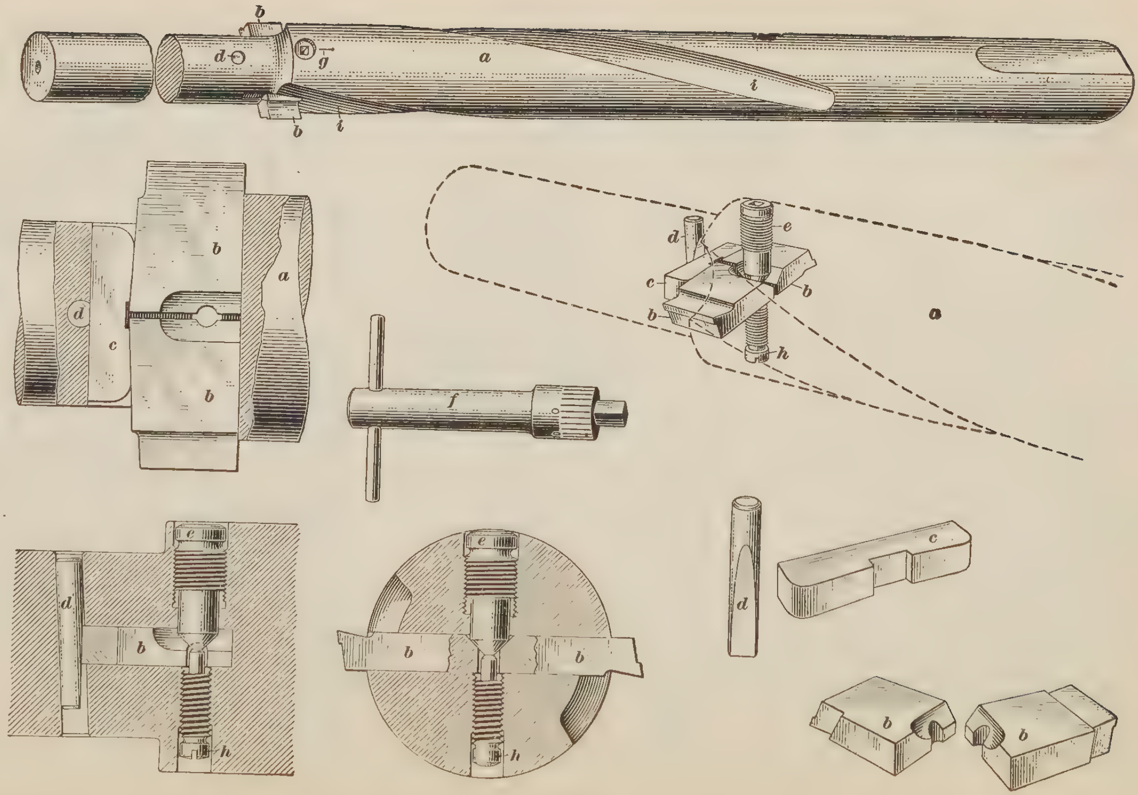


Fig. 3

be held rigidly in the bar, for otherwise the hole will not be true. Turret lathe boring bars are generally supported at both ends, having an extension, or pilot, which enters a bushing in the chuck or in the spindle for support. An adjustable cutter boring bar is shown at *a* in Fig. 3. This bar has two cutters *b*, made right and left hand, and located in a radial slot through the bar. They are held in place by a key *c* and a tapered pin *d*. The cutters are adjusted to the size of the hole by a screw *e*, having a 90-degree point that enters a similar taper formed between the inner ends of the cutters, as shown. The adjusting screw *e* is operated by a square-end wrench *f*, which is graduated to indicate, in connection with the zero mark *g* on the bar *a*, .001-inch changes in diameter of

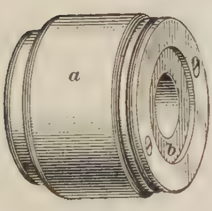


Fig. 4

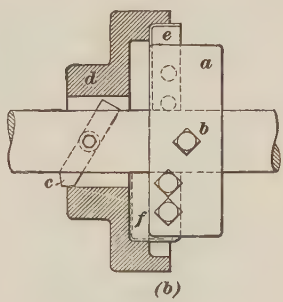


Fig. 5

the cutters. A screw *h* locks the adjusting screw *e* in place. A right-hand flute *i* from the front of each cutter serves to take care of the cuttings that do not otherwise escape from the hole.

For accurate work it is customary to rough-bore, finish-bore, and then ream the hole. The roughing cutter is usually ground or set from .015 inch to .02 inch undersize and the finishing cutter is ground or set from .005 inch to .007 inch undersize to leave stock for reaming.

10. Boring-Bar Pilot Bushings.—The bushings in which the pilots of boring bars are supported are usually made of cast iron, or of cast iron with a hardened-steel core, or they are made with a master bushing *a*, as shown in Fig. 4, that

fits the hole in the chuck and is bored to receive an interchangeable pilot bushing *b*. The pilot bushing is ground to a sliding fit on the pilot of the boring bar and remains stationary with the bar while the master bushing *a* revolves around it. There is an oil chamber in the master bushing.

11. Boring-Bar Cutter Head.—Boring and facing operations can be performed simultaneously by using a cutter head having one or more cutters, as shown in Fig. 5. The cutter head *a* is shown fastened to the boring bar by the setscrew *b* that bears on a flat surface milled on the bar. While the tool *c* is boring the piece *d*, the tools *e* and *f* mounted on the cutter head are counterboring two diameters, as shown.

12. Floating Reamer Holders.—Reamers that are rigidly held in the turret may make the holes either oversize or tapered. To prevent this trouble a floating holder, as shown in Fig. 6, is used. It has a socket *a* with a stem *b* turned on it to fit the hole in the turret. The shank *c* of the reamer

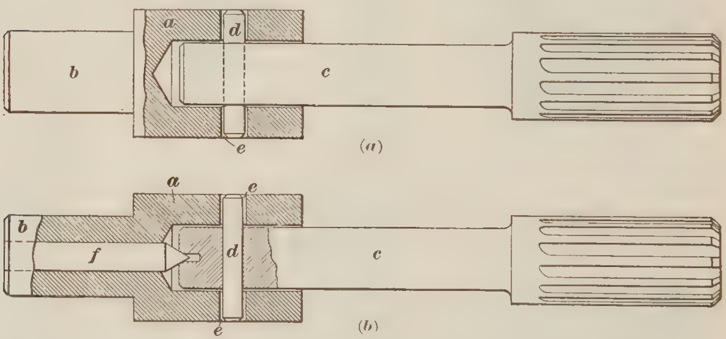


Fig. 6

fits loosely in the socket, and is drilled to receive the driving pin *d*, which has a driving fit in the shank *c* and a loose fit in the holes *e* in the socket. In the type of holder shown in *a* the reamer droops and has to be assisted into the hole. This can be avoided by using a centering plug *f*, shown in (*b*), that centers the reamer and also takes up the thrust. However, if the hole in the turret does not line up with the

spindle, owing to wear of parts of the lathe, the plug *f* will also be off center and throw the reamer out of alinement.

13. Floating Die Holder.—The illustration in Fig. 7 shows a holder for either solid or adjustable dies. The head *a* is separate from the shank *b* to which it is fastened by shoulder screws *c*. The holes through which the bodies of these screws pass are made a little large, an allowance being made for a slight lateral or "floating" motion to the die head *a*. This enables the die to center itself upon the work, thus overcoming any slight inaccuracy in alinement and securing a more perfect thread than when the holder is solid.

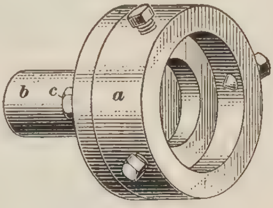


FIG. 7

STANDARD TURRET TOOLS

14. Universal Turners.—For bar work the reduction of stock is quickly accomplished by box tools known as *universal turners*. The illustration in Fig. 8 (*a*) shows a universal turner with the cutting tool *a* placed tangent to the work. In this position the tool may be used for a wide range of diameters of work. Adjustment of the cutter for different diameters of work may be made by moving the cutter slide *b* in or out by a rack *c*, view (*b*), and pinion *d* in the back of the slide. The pinion *d* is at one end of a short vertical shaft *e*; at the top of this shaft is a worm-wheel *f* that may be turned by the worm *g* on the shaft *h* of the hand wheel *i*. For delicate adjustments a graduated dial *j*, view (*a*), is placed on the shaft *h*.

When the cut is finished the cutter is quickly withdrawn from the work by the lever *k* that is connected to the vertical shaft *c*, and easily reset for duplicate work by means of the dial *j*. The thumbscrew *l* locks the gear mechanism so as to maintain the setting of the cutter. The roller back rests *m* are held in hardened and ground holders adjusted independently in guides in the body of the tool. The base *n* of the attachment is bolted to one of the faces of the turret.

15. Relative Position of Cutting Tool and Back Rest in Box Tools.—The box tool carries the cutting tool, and guides and supports the work. When the roughing cut is being taken, the tool should be ahead of the back-rest support, as the work is better supported when it is of nearly correct diameter. If, however, the box tool is used for a second operation on the

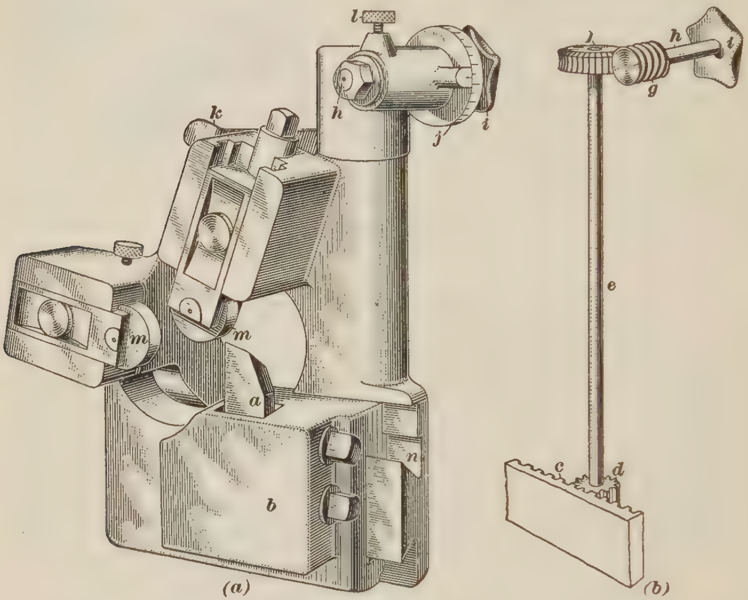


FIG. 8

work, the back rest should lead the tool, as it is important for a finishing operation that the work is held correctly before the cut is taken. Usually, provision is made to change the position of the back rest by hand. In some box-tool designs the back-rest support may be made to lead or follow the cutter by reversing the slide to which the support is attached.

16. Box-Tool Back Rests.—The back rests used in box tools are either of the **V** type, or the roller type illustrated in Fig. 8. The rollers reduce the friction and are not so liable to mar the work as the **V** type, but when the diameter of the work is small the roller back rests cannot be brought

close enough to the center to support the work equally, and the **V** type of back rest should be used.

17. Facing Head.—Facing heads are tool holders that are either bolted to the turret faces or have shanks that fit the turret holes. They are made to hold a variety of cutting tools for facing and turning. To insure rigidity the overhang of a facing head from the turret must not be too great unless proper support can be obtained by the use of a pilot bar, otherwise the tools are liable to chatter. Some facing heads are designed so that a portion of the head forms a support directly

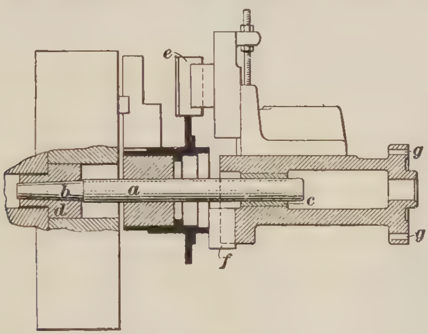


FIG. 9

under the cutting edge of the tool. Such a facing head is shown in Fig. 9. It has an arbor *a* with a pilot *b*. The arbor is supported in a bushing *c* in the head and the pilot is supported in a bushing *d* held in the chuck bore.

18. The cutting tools *e* and *f* are carried in slides mounted on the arms of the head or clamped in suitable slots or holes by screws, or both. The gibs in the arm slides must be adjusted tightly before the cutters are inserted, as adjustments of the cutters in the arms are more easily made after the gibs are tightened. The head is bolted to one of the faces of the turret by four bolts through holes *g* in the body.

Facing heads should not be used for first roughing cuts. It is better to have a roughing tool held in the cross-slide of the lathe get under the scale first and do the heavy roughing. The truing of the work and the finishing may then be done

by tools held in a facing head. Such tools that are set for facing should have a clearance of from 5 degrees to 7 degrees and a top rake of from 5 degrees to 10 degrees. When too much clearance angle is given to tools mounted in a facing head they are subject to chatter. Facing heads are made with two, three, or four arms.

FORMING TOOLS

19. Forged Forming Tools.—Forming tools, when forged from bar steel and filed or machined to the given form, are similar to the forged forming tools used in the engine lathe. The main objection to the filed forming tool is that only a limited amount of grinding can be done before the tool will change its shape.

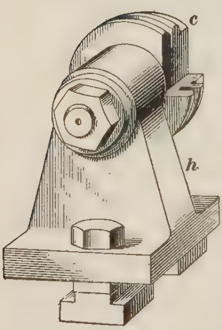


FIG. 10

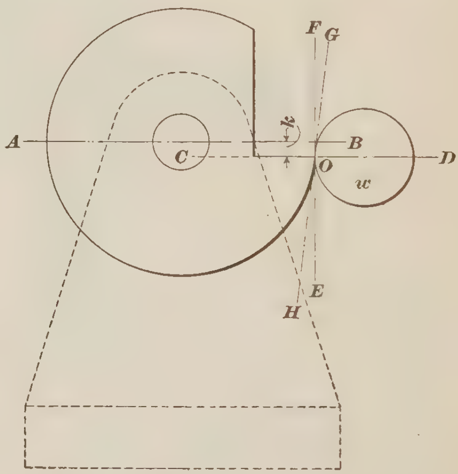


FIG. 11

20. Circular Forming Tools.—A circular forming tool is shown in Fig. 10. A circular cutter *c* has been formed so that its cutting edge will conform to the required shape of the work. A notch is cut on one side of the cutter so that the lower face *C D*, Fig. 11, is slightly below the center *A B* of the cutter. This amount *k* varies with the diameter of the cutter. On a 2-inch cutter, from $\frac{1}{8}$ to $\frac{1}{4}$ inch is sufficient. The holder *h*, Fig. 10, is made to hold the center of the cutter above

the center of the work, thus bringing the top face of the cutter *C D*, Fig. 11, in line with the center of the work *w*. The object of cutting the notch in the cutter below its center and then raising the cutting edge to the center of the work is to give the tool clearance. If the tool and the work are set at the same height, Fig. 12, they will touch at the point *O*, which is in a line joining the centers. The circular forming tool has the advantage that it can be ground repeatedly without changing its shape, and it is easier to make than the forged and filed tool.

21. Cutting the face of the notch on the tool below the center will slightly change the outline of the cutting edge,

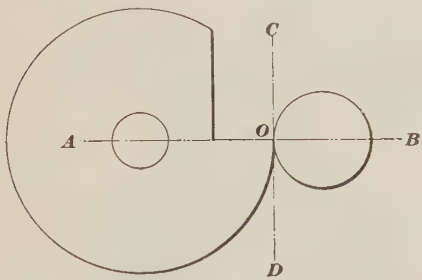


FIG. 12

FIG. 13

because a section of the cutter on the line *A B* is different from the section on the line *C D*, Fig. 11. If the cutter is $2\frac{1}{2}$ inches in diameter, the difference in section caused by cutting from $\frac{1}{8}$ to $\frac{1}{4}$ inch below the center line will not be sufficient to cause trouble in ordinary work. If an exact outline is required, the cutter must be formed to give the exact outline on its cutting edge and not on the diametrical section. This form of tool is sharpened by grinding the top cutting face, after which the cutter is revolved sufficiently to bring the cutting edge level with the center of the work. The circular forming tool may be mounted on a fixed support *h*, as in Fig. 10, or on a swinging arm that permits changing the slope of the cutting edge to the work.

22. Straight-Faced Forming Cutters. — Straight-faced forming cutters are shaped along the front edge the same as

ordinary forming tools, so that the section across the top cutting face *a*, Fig. 13, gives the desired outline. They are so set in the holder that the front face *b* has a slight angle of clearance. The top face *a* is ground flat and set at the same height as the center of the work.

23. Straight-Faced Forming Cutter Holders.—Holders for straight-faced forming cutters are made in a great variety of design. In the holder shown in Fig. 14, a heavy holder *a*

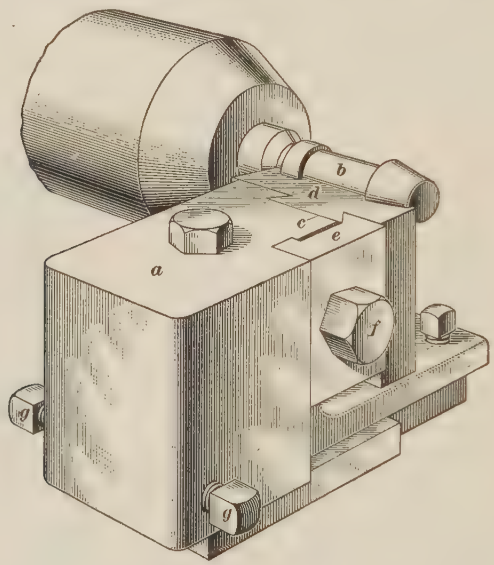


FIG. 14

is bolted to the cross-slide in front of the work *b*. In the front face of the tool block is cut a **V** slot *c* into which is fitted the dovetailed part of the forming cutter *d*. The cutter is clamped to the block by tightening the strap *e* against it by means of a bolt *f*. This style of holder is used for wide cutters and is therefore made heavy. In order to prevent the cutter from slipping back under a heavy cut the clamping screws *g* are provided.

Straight-faced forming tools are used for forming irregular shapes in brass and other soft metals that are cast to shape.

Several attachments are made to hold such forming tools on the cross-slide carriage. Of these, the *vertical-slide forming attachment* and the *undercut forming attachment* are the most important.

24. Vertical-Slide Forming Attachment.—Forming tools are operated by means of a vertical-slide rest, as shown in Fig. 15. Here a vertical slide is clamped to the back of the

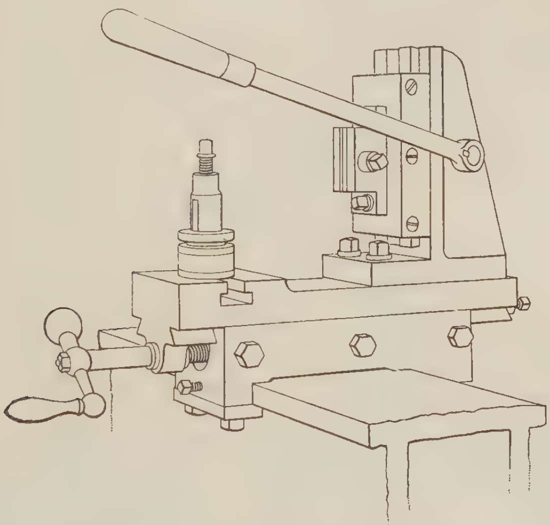


FIG. 15

ordinary cross-slide. When this slide is used with the forming tool, the cutting edge moves in a line tangent to the work. In Fig. 16 is shown a side elevation with the forming cutter *c* in place. The cutting edge follows the line *A B* as the tool moves down in the slide. The cutter *c* is clamped to the block *b* by a bolt *d*. The slide *s* carrying the block *b* travels on the guide *t*, and is controlled by the hand lever *f*. The work is shown at *w*.

25. Form of Tool to Prevent Chattering.—When tools are fed toward the center, as in Fig. 11, the entire cutting edge is acting at once. If the cut is broad, the work will spring

and chatter. When the vertical slide is used, the cutting face of the forming tool may be ground with considerable slope to one side so as to prevent chattering. A tool thus ground is shown in plan and elevation in Fig. 17, and also the shape of the work *w* that this particular form of tool would produce. As the tool is fed downwards past the work, the edge or point *a* will be the first to cut. When the tool is fed still farther along, the point *a* soon cuts to its depth and passes by the work, while

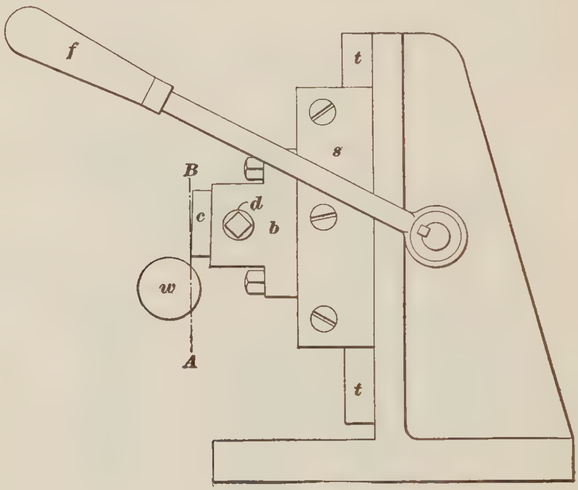


Fig. 16

other points along the cutting edge are approaching the work. By the time that the last point *b* of the cutting edge has reached the work, the point *a* and all the other points along the edge have passed by, having done their respective parts in the cutting. Since the action is a shaving one, whatever the total length of the edge of the forming blade may be, only a small part of it cuts at a time.

Forming cutters for steel require more top rake and less clearance than those used on castiron. In forming steel it is good practice to polish or burnish the tools on top, as this causes the chips to slide off the tool freely and prevents them from sticking to the tool and leaving a rough surface on the work.

26. Special Forming Heads.—When very much forming is to be done, a forming head is used that holds two forming cutters, one at the front and the other at the back of the work, as shown in Fig. 18. The front and back forming blades *a* and *b* are held in tool blocks *c* and *d* that slide in the base *e* and that are operated by the same screw, which has a right-hand thread at one end and a left-hand thread of equal pitch at the other. By turning the hand wheel *h*, the blocks *c* and *d* advance or recede from the work at a uniform speed. When in use, the blocks and blades are so adjusted that each blade cuts to the same depth. The hand wheel *h* is then turned until the blades have entered the work the necessary depth.

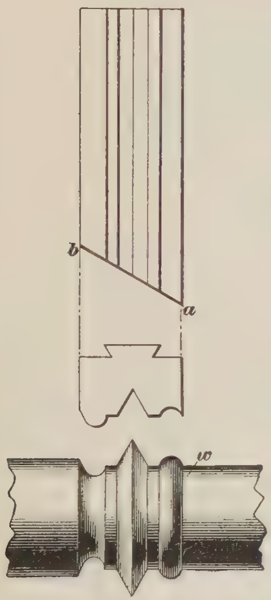


Fig. 17

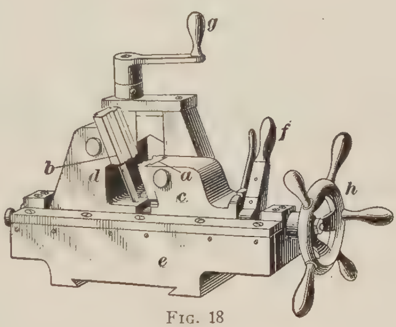


Fig. 18

27. Form of Blades in Double-Blade Attachments.—In the forming attachments using two forming blades, the edges of the blades are not exactly alike. The back tool *b*, Fig. 18, may be of the complete outline; the front tool *a* is similar, but has notches cut along its face, as shown in Fig. 19. The back tool *b* has a regular outline, but the edge of the front tool *a* is slightly broken. The result is that the shaving is broken, the high parts of the front tool doing the cutting at the points *i*, and the back blade taking all the remaining parts. The strain on the work and the cutters is very much relieved. When the

work is nearly completed, the front blade is slightly backed away from the work by moving the lever f, Fig. 18, allowing the tool at the back to finish the work smooth. When two

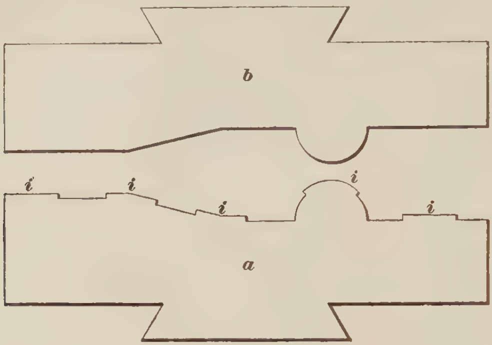


FIG. 19

cuts are thus taken the work is quite well balanced, but to steady it still further, a steady rest with **V** jaws, operated by the crank g, is used.

28. Combined Parting and Forming Tool.—When the head of the piece to be cut off is curved, as in the case of round-headed screws, circular forming tools may be employed.

FIG. 20

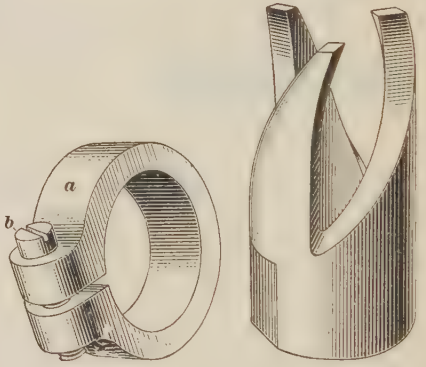


FIG. 21

In Fig. 20 is shown a section through a circular forming tool that could be used as a cutting-off tool, and at the same time as a forming tool for the head of the work.

MISCELLANEOUS TURRET TOOLS

29. Solid-Blade Hollow Mill.—Hollow mills are useful for the rapid removal of metal. A hollow mill having three teeth which cut on the ends is shown in Fig. 21. There is a slight taper in the hole, having its smallest diameter at the

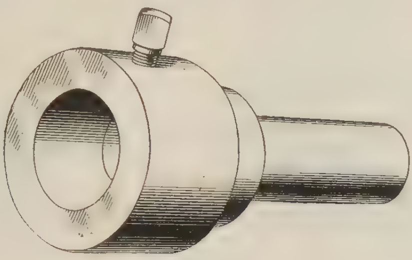


FIG. 22

cutting ends. As the teeth of a hollow mill are ground on the ends only, resharpening slightly increases the inside diameter. To spring the teeth inwards to their proper diameter, a collar such as is shown at *a* is clamped tightly around the teeth by a binding screw *b*. The holder for the solid-blade hollow mill is shown in Fig. 22.

30. Inserted-Blade Hollow Mill.—Adjustable hollow mills are made in several styles. The finishing hollow mill, Fig. 23, has two inserted blades *a* that do the cutting, and the other

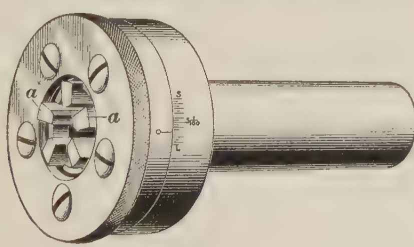
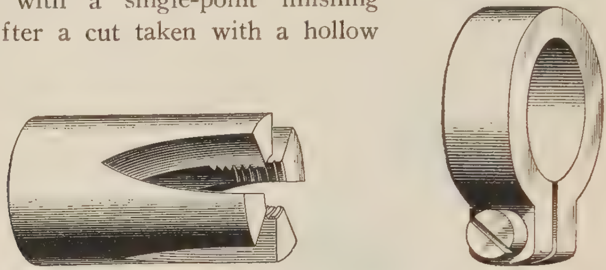


FIG. 23

blades are back rests to steady the work. In some types, all the blades are adjusted at once after the manner of the self-opening dies described later in this Section.

A cut made with a hollow mill cannot be depended on to be perfectly true. As such tools are broad-nosed and usually poorly supported because of their considerable overhang from the tool holder, they are likely to chatter and cause the cut to be untrue. For this reason a finishing cut should always be taken with a single-point finishing tool after a cut taken with a hollow mill.



(a) (b)

FIG. 24

31. Spring Die.—In Fig. 24 is shown a form of hollow, or spring, die that is held in a holder like that shown in Fig. 22. The die is adjusted to cut to the exact size desired by springing the jaws together by means of a clamp shown in *b*.

SPECIAL TURRET TOOLS

32. Tools for Special Purposes.—The turret tools that have been described are the standard tools and include the box tools in which the work is supported by the tool holder while the blades are cutting; also the small turret tools, like reamers, drills, counterbores, etc., that are often held in floating tool holders, and the threading tools. A great variety and combination of shapes of turret tools exist in addition to the tools already described. Most of these special tools have been designed to perform to advantage particular operations on special classes of work.

33. Turret Work.—It is often necessary, while the tool in the cross-slide is operating, to have the work supported on the turret end by a center, such as is shown in Fig. 25. This is a hardened center with a flat surface on the shank for the turret setscrew.

34. Turret Duplex Tool Holder.—The tool holder shown in Fig. 26 holds two tools at right angles to each other. A vertical stud *a* pivots the swinging holder *b* to bring either tool in line with the spindle, after which the nuts *c* lock the holder firmly in place. To secure correct spindle alinement of each holder, hardened stop-pins are put through the holes *d* and *e* into the body of the tool holder.

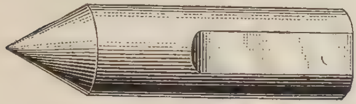


Fig. 25

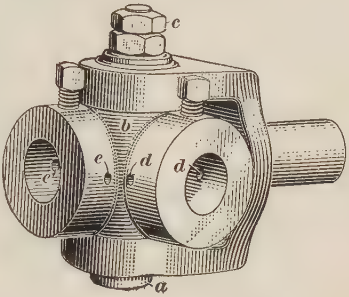


Fig. 26

35. Turret Slide Tool.—The slide tool shown in Fig. 27 is intended for boring holes too small for the standard boring bars to pass through, also for recessing, cutting grooves, backfacing hubs, etc. The lower hole in the slide *a* is for a tool that is to operate on work with a hole of small diameter and the upper hole for a tool that is meant to bore larger holes. The holder has tapped holes in the back and is fastened to one of the faces of a hollow hexag-

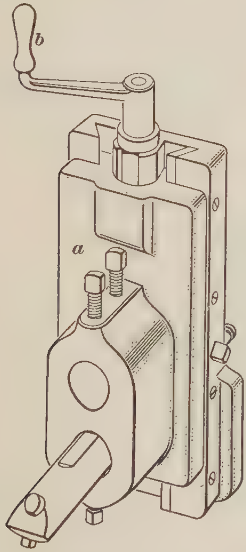


Fig. 27

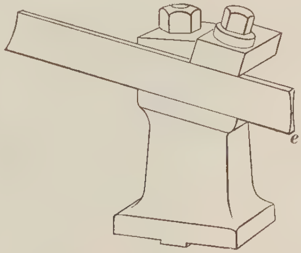


Fig. 28

onal turret by screws that are inserted from the inside of the turret. The slide may be raised or lowered to adjust the height

of the cutting tool, by means of a screw operated by the handle *b*.

36. Turret Inverted Parting Tool.—This tool, Fig. 28, is at the back of the machine and, consequently, the blade is

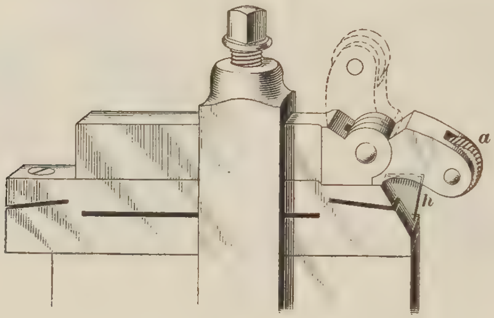


FIG. 29

inverted, with the cutting edge at *c*. By holding the cutting blade in a sloping position, as here shown, it will have top rake, which will add to its efficiency.

Holders for two or more cutting-off blades are used for making washers, collars, etc. The cutting blades are spaced

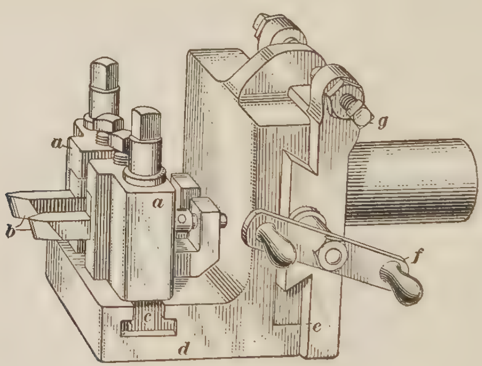


FIG. 30

by metal pieces between them. A slight vertical adjustment of the cutting edges can be made by setting the blades farther in or out of the holder.

37. Cross-Slide Combination Parting and Nurling Tool. In Fig. 29 the parting tool is clamped under the nurling tool. The nurling tool is jointed, so that when the parting tool is used, the nurl *a* may be raised to the position shown by the dotted lines. While the screw is being made, the nurl should be turned back and the parting tool *h* used to cut a shallow notch in the work, which will define the thickness of the head.

38. Turret Facing and Recessing Tool Holder.—A tool holder that holds tools for facing and recessing operations, and that is adjustable in several ways, is shown in Fig. 30. The shank of the tool is gripped in one of the turret holes. The

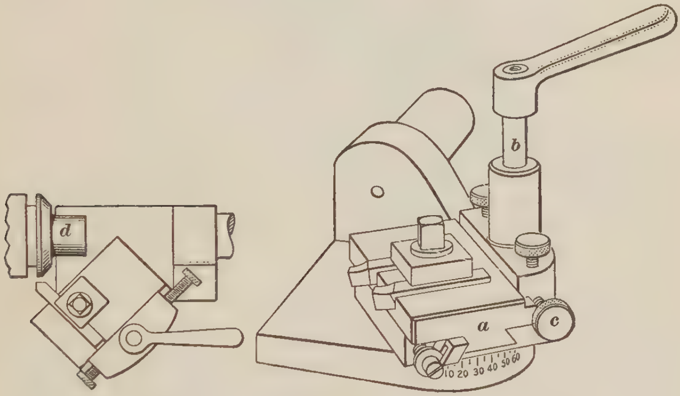


FIG. 31

two tool posts *a* holding the cutters *b* are adjustable in the slot *c* while the block *d* can be moved in or out on the guide *e* by the handle *f* on the hand screw. Stop-screws *g* are provided for regulating the motion of the slide in either direction.

39. Turret Adjustable Angle Rack Tool.—For finishing short tapers such as are used on valve seats, the adjustable angle rack tool, shown in Fig. 31, may be used. The slide *a* can be made to swivel through an angle of 90 degrees. Graduations are provided for setting the slide to the required angle, after which it is clamped in place by a binder screw handle *b*. An adjustable stop-screw *c* at each end regulates

the travel of the slide. At *d* is shown an example of work that can be machined with this tool.

40. End-Forming Turret Tool.—The roller back-rest tool for facing and rounding the ends of shafts, bolts, etc., shown in Fig. 32, is made to hold special cutters *a*, view (*a*), that are dovetailed in the block *b* and held by the screw *c*. The back-rest rolls *d* and their studs are made of hardened steel and are mounted on a swing jaw *e*. Adjustment of the rolls to the diameter of the work is accomplished by the screws *f*,

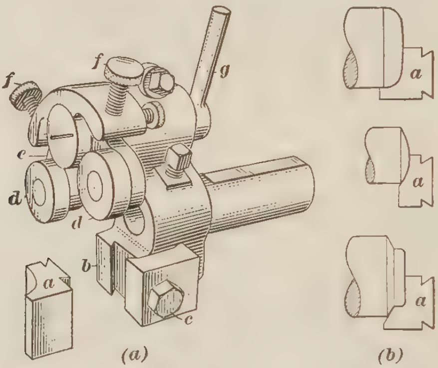


FIG. 32

and the rolls are then clamped in position by the handle *g*. The cutters *a* are presented to the ends of the work as shown in view (*b*).

41. Taper Turning Turret Tool.—The turning of tapers on work may be accomplished either by ordinary lathe tools held in the cross-slide, or by special tools held in the turret. Such a special tool is illustrated in Fig. 33. The taper is turned by a tool *a* mounted in the slide *b*, and the work is supported by the back-rest *c* adjustable in the slide *d*. The slide *b* is able to move in or out on the body *e* that is provided with a hollow shank to fit one of the holes in the turret. In operation, the movement of the slide is controlled by a taper bar *f* inserted between a stationary block *g* and the slide *b*. When the turret moves toward the headstock, the end of the

bar *f* strikes a stop on the headstock causing the bar to be forced between the block *g* and the slide *b*, thus forcing the slide outwards. As the bar *f* is made with a taper conforming

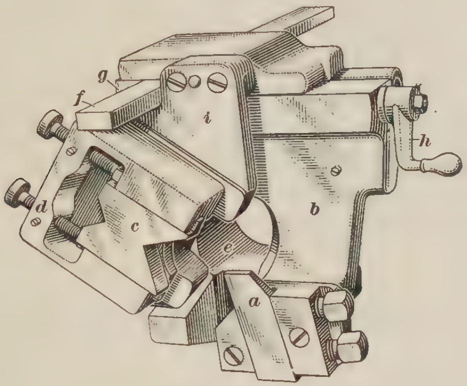


FIG. 33

to the taper to be cut, the tool *a* is thus made to follow the outline of the taper. The slide *b* is provided with a spring to keep the taper bar firmly against the block *g* while the tool is cutting.

42. At the top the slide moves over the body along a dovetailed bearing with a gib to adjust for wear, and at the bottom the slide has a ground surface that moves over a hardened and ground roller in the body so as to minimize friction. The tool is adjusted to the diameter of the work at the beginning of the cut by a screw operated by the handle *h*, Fig. 33. By means of a micrometer dial fine adjustments of the slide *b* can be obtained with the screw for the purpose of taking finishing cuts. The bar *f* is straight on one edge and tapers on the opposite edge. In order to cut a taper on work, it is only necessary to plane the bar to a taper one-half of that required on the work; thus, if the desired

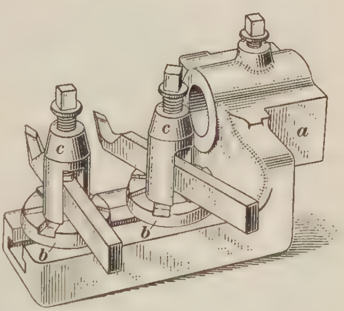


FIG. 34

taper is $\frac{1}{2}$ inch per foot, the bar *f* must be planed to a taper of $\frac{1}{4}$ inch per foot.

43. Offset Double Tool Post Holder.—A form of holder for two tool posts is shown in Fig. 34. The part of the holder on which the tool posts are mounted is offset and two cutting tools may be used simultaneously for turning, facing, or cutting-off operations. The holder has a hold in the part *a* that is held in the turret, to accommodate long work such as bars or rods, and the tools can be adjusted for height by using the step collars *b* under the tool posts *c*.

TURRET LATHE OPERATIONS

SETTING AND HOLDING WORK

44. Testing Alinement of Turret Lathe.—For accurate operations on the turret lathe the spindle must be correctly alined with the turret holes.

A simple method of testing turret screw machines is to put a piece of steel in the chuck and turn it down absolutely true to the size of the turret hole. Then by bringing the turret up to this piece it can be determined whether the machine is in alinement or not. If the piece enters the hole smoothly and without resistance, the machine is in line, but if not, it will show which way it is out.

45. Chucking of Work in Turret Lathe.—If work other than rods or bars, which are supported in the headstock spindle, is to be machined in a turret lathe, standard two or three-jaw chucks are used to grip the work according to the size and shape of the piece. Frequently, jaws especialy fitted for the work are used. If the pieces are to be made in large numbers and the jaws of the chuck exert an uneven pressure on the work, due to the irregular outline of the piece, a slight change in the pattern which does not materially affect the design of the piece, may often simplify the chucking.

46. Centering Rough Work in Chuck.—Two chucks are used to center rough work, such as the heads of forged bolts whose bodies are to be turned. Usually the heads of such bolts are more or less off center and, if held in a universal chuck in the spindle, the bodies would not be in line with the hole in the turret. A universal chuck is mounted in the turret and a two-jaw chuck with floating jaws is carried in the regular chuck in the spindle. In operation, the body of the bolt is placed in the universal chuck, its head coming where it may. The turret is then moved toward the headstock until the bolt head comes between the floating jaws of the chuck, in which it is then firmly gripped. The universal chuck is then opened and backed off the bolt body, which is then ready for turning.

47. Proper Place for Setting Tools in Turret Lathe. Tools for heavy roughing and facing operations are, with few exceptions, held in the tool post of the lathe, as are also the tools for rough-boring diameters too large to be bored with boring-bar heads. If the work has to have a hole in it and such a hole has not yet been cored, a two-lip twist drill held in the turret should be used for drilling the hole. If the hole in the work is cored, a suitable core drill should be used

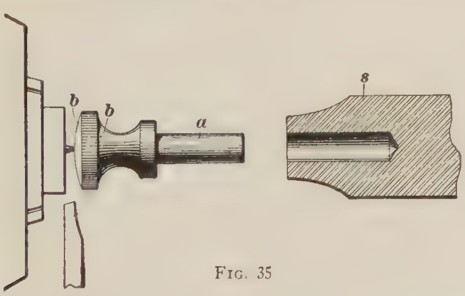


FIG. 35

if the hole is small; for larger holes and accurate work, a roughing and a finishing boring bar, held in the turret, are used. The turret also holds tools for reaming the bored holes, and tools for finishing the outside surfaces of the work. Reamers generally follow the finishing boring bars for accurately sizing the hole. A sample piece of work, correctly finished, which is

held on a supporting arbor in the head is a dependable gauge for setting the tools and stops.

48. Steady Rest for Turret Lathe Work.—In some cases, a steady rest must be used in the turret for supporting work. Suppose the piece shown in Fig. 35 is to be made. The body *a* would first be turned to size. A hardened-steel sleeve *s*, shown in section, which has been bored to fit over the part *a*, would then be slipped over it by moving up the turret. This supports the work while the head *b* is being formed and the work cut off. This method of supporting the end of the work may be applied to many classes of work.

MACHINING OPERATIONS

49. Operation of the Turret Screw Machine.—Suppose, for example, that a large number of screws with round nurled heads, as shown in Fig. 36, are to be made. Then the setting-up

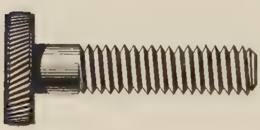


Fig. 36

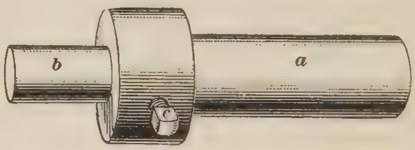


Fig. 37

of the turret screw machine includes setting the various tools in the turret and in the cross-slide, adjusting the stops to determine the length of cuts, and adjusting the cutter blades to turn the correct diameters. A rod is put through the spindle, and the collet is so arranged that the rod can be gripped rigidly, and also so that when it is released the feed will move the rod through the spindle.

50. Stop-Gauge.—The first tool used in the turret is the adjustable stop-gauge shown in Fig. 37, which determines the correct length of stock for the work. The shank *a* is clamped in the turret and the adjustable stop *b* so clamped by the set-screw *c* that when the turret and slide are at the full length of their travel toward the headstock and the rod is fed up to the end of the stop *b*, the correct length to make the screw will

project from the chuck. The rod having been clamped, the turret is moved back and revolved to bring the first turning tool into place.

Another form of stop is shown in Fig. 38. A rod *a* slides in bearings *b* on top of the headstock. Its extension to the

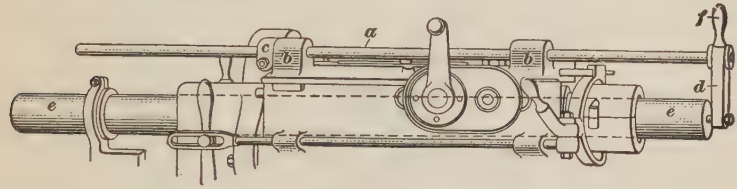


FIG. 38

right is regulated by a clamp collar *c*. On the inner end is a swinging arm *d* that drops down and stops or limits the projecting length of the rod *e* from the spindle. When the tool is moved toward the end of the rod *e*, the arm *d* must be swung out of the way by the handle *f*.

51. Roughing Box Tool.—The first turning tool to be used in the turret is the roughing box tool, shown in Fig. 39. The shank *a* is held in the turret, and the blade *b* is clamped in place by the screws *c*. The blade is adjusted to turn the

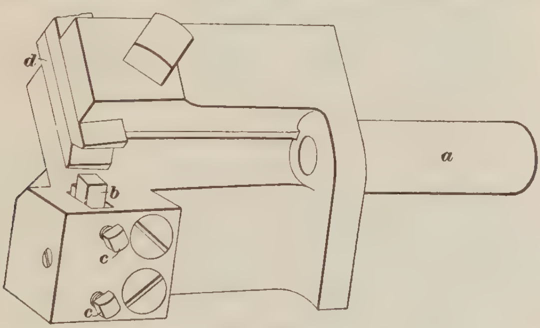


FIG. 39

correct diameter by a series of trials. The **V** back rest *d* opposite the tool *b* must be adjusted so that it just supports the end of the work. Fig. 40 is an end view of the box tool, showing how the blade *b* comes against the work *e* and how the back rest *d* supports it.

52. Turret lathe tools do not need so much keenness as those on ordinary lathes because the cut is tangential and the work has good back support. With the tool shown in Fig. 40,

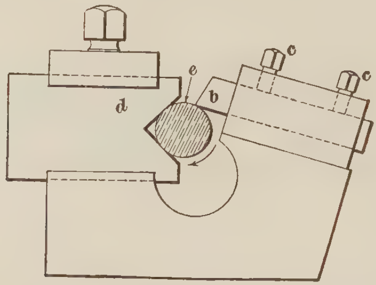


Fig. 40

or with the one in Fig. 39, a cut may be taken over the body of the screw up to the shoulder under the head. If the bar is iron or steel, a supply of lard oil is kept running on the work to prevent it and the blade from heating.

53. Finishing Box Tool.—The same principle as in the roughing box tool is used in the finishing box tool, except that

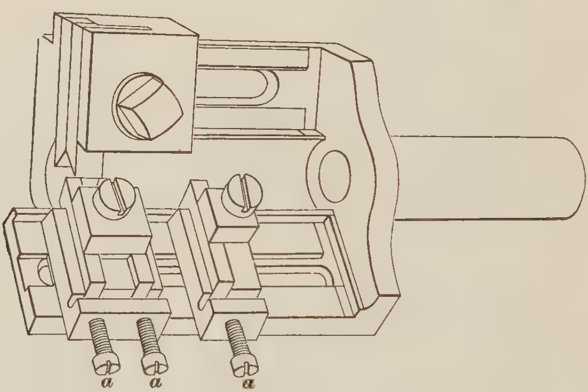


Fig. 41

the blades are made and adjusted to cut similarly to a broad-nosed lathe tool. The blade for the rough cut is ground on the same principle as the roughing tools for lathe work. As

shown in Fig. 41, a finishing box tool has a number of cutters, each of which may be adjusted to cut to a given depth by the setscrews *a* at the end of the blades. The blades are used when it is necessary to finish parts to different diameters at the same time. Each blade is so adjusted along the length of the box tool that it will turn the required length of work to that particular diameter. For the screw in Fig. 36, only the first blade in the tool will be used. This blade will be adjusted to finish the body of the screw to the correct diameter.

54. Pointing Tool.—Before cutting the thread, the end of the body should be beveled, or chamfered, so that the die will make a clean start. This is done with the pointing tool, shown in Fig. 42. The end of the cutter *a* has the same bevel

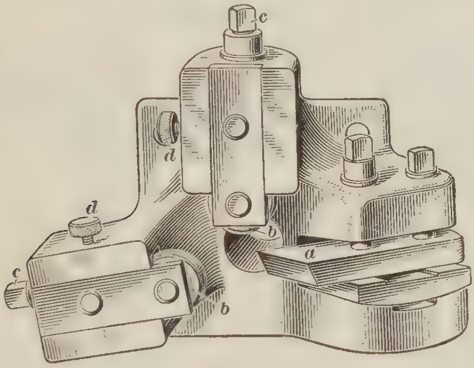


FIG. 42

as required on the end of the screw. The rolls *b* form the back rest for the work and are adjusted in their slides by the screws *c*. The nurled thumbscrews *d* hold the rolls in position. The hole in the back of the body is needed when the end of the work must pass through it and be supported on a center in the turret.

55. Dies and Die Holders.—The threads are cut with dies on all screw machines. For work of small diameter and short length the round adjustable solid die *a*, Fig. 43, is most commonly used. The die body is split and has an adjusting screw *b*. The die is held in the holder by a screw *c*.

56. In order that the thread will be cut an exact length on each screw, a releasing die holder, as shown in Fig. 44, must be used. The dies are fastened by the screws *e* in the holder *a*. The stem *d* passes through a sleeve that has a flange on one end and that is held in the turret. When in the position shown in the illustration, the holder is free to revolve in the sleeve. When the die is fed against the work, the holder slips back in the sleeve until the pins *b* and *c* engage each other. The pin *c* will then keep the die holder from revolving. As soon as the holder ceases to revolve, the die will begin to cut, and after cutting a few threads it will feed itself along the work.

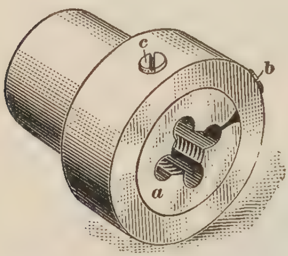


Fig. 43

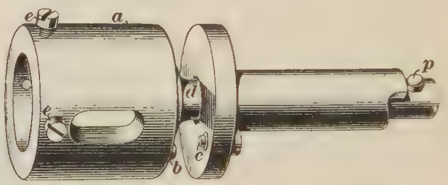


Fig. 44

57. If provision were not made to stop it as the work continued to revolve, the die would screw up to the shoulder and destroy the thread. With the holder shown, the die will feed along the work, the turret being made to follow it, until the turret slide reaches its stop. The work, however, continuing to revolve, will feed the die still farther, and bring the holder with it until the pins *b* and *c* disengage, whereupon the holder again revolves with the work, thus stopping the cut. In the meantime, the direction of the lathe is reversed and the turret moved back by hand until the backing pin *p* engages the notch cut in the end of the sleeve. The holder is thus kept from turning backwards, and so the die is backed off the screw. A sizing die is sometimes run over the thread. The nurling of the head and the parting of the finished screw are done by tools in the cross-slide.

58. Nurling.—The nurling tool is shown in Fig. 29. Its hardened-steel roll *a* has teeth, so that, when rolled against the

work, they will impress the design in the softer metal. Where the width of the nurl is equal to or greater than that of the work, the nurling operation consists merely of bringing the toothed roll squarely and evenly against the work with considerable force, and holding it there until the work has made several revolutions. If the work is much wider than the nurl, the nurling is sometimes done by finishing, in succession, widths equal to the nurl until the whole length of the work is covered. Another method is to feed the nurl along the work in the same manner as a threading tool, and to repeat the cuts until the impressions are made the required depth.

59. Parting Tool.—The parting tools used in the turret lathe are similar to those used in a regular lathe, and are held in the cross-slide. Combination parting and forming tools round the head and cut off the stock at the same time.

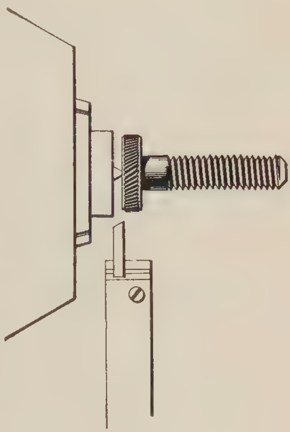


FIG. 45

60. The parting tool should leave the head of the screw bright and smooth, with no projection in the center. If the tool is ground square across its cutting edge, the work will break off before the cut is quite finished. This trouble may be avoided by grinding the cutting edge of the parting tool beveled, with its projecting point next to the screw head and setting its top level with the work center, as shown in Fig. 45. The tool is fed in until it also removes the conical point of metal from the stock.

61. Boring Cone Pulleys.—In Fig. 46 is shown a turret lathe fitted up to bore a cone pulley *k*. The hub is roughed out by a cutter on the bar *c* and finished by the cutter on the bar *d*. The steps of the cones are bored and the faces finished by the special tools *a* on the bar *b*; the outer edge of the pulley is faced and a finishing cut taken on the inside of the largest

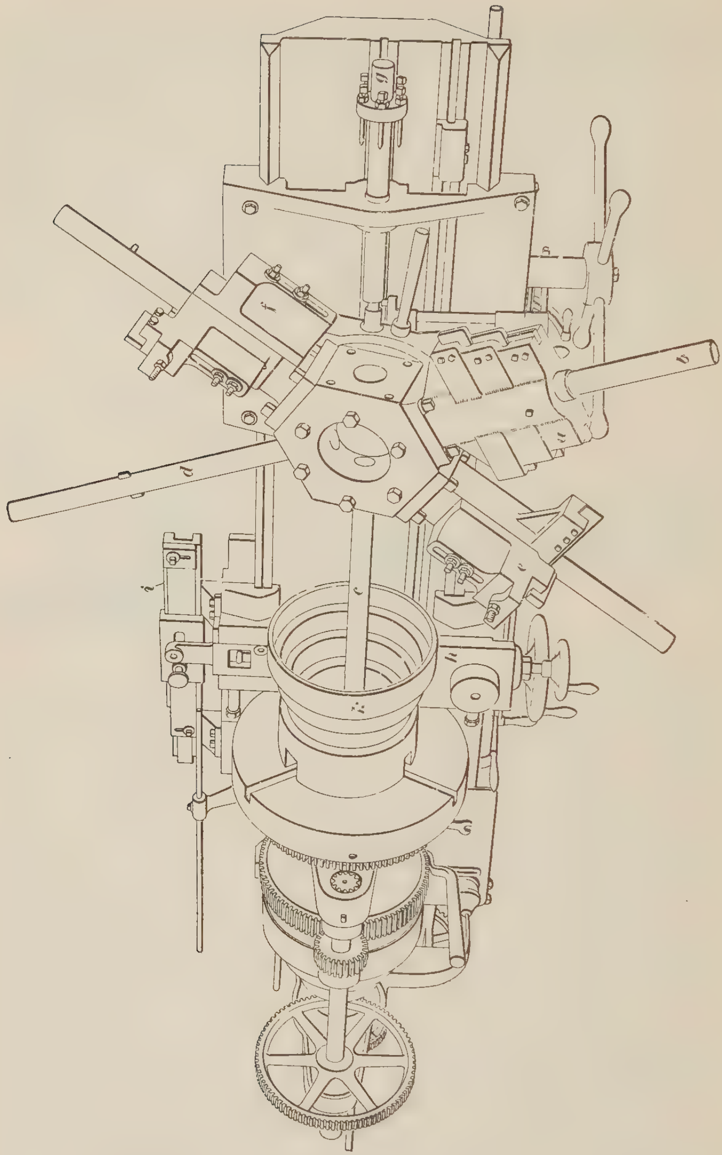


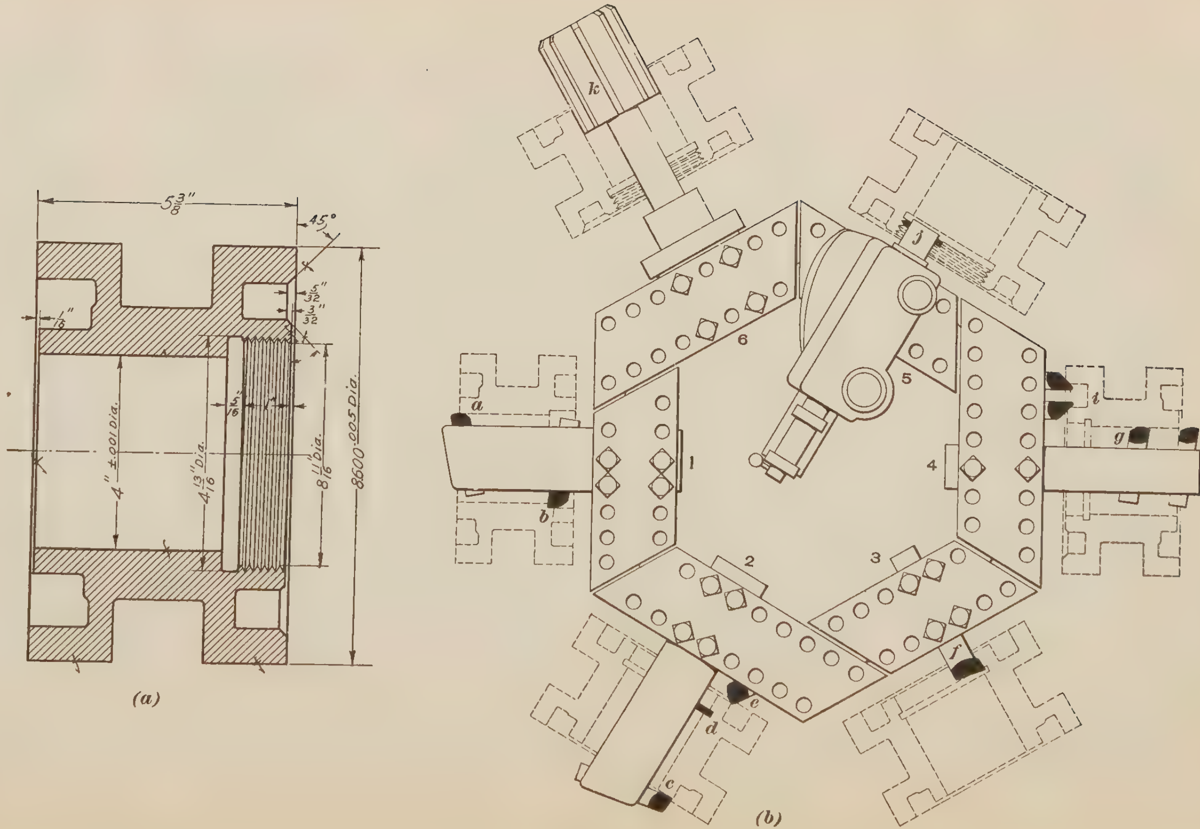
Fig. 46

cone by the heads *e* and *f*. All the tools are provided with extensions on the ends of the bars; these fit bushings in the spindle of the machine or the chuck and thus furnish a guide for the end of the bar. At *g* a series of screws are arranged to act as stops for the various tools, each one of which can be adjusted separately. In the illustration, the carriage *h* and the taper attachment *i* are not in use. These cone pulleys may be finished on the outside on the same machine by mounting them on arbors and turning them with tools placed on the carriage *h*.

62. Single Chucked Work.—Castings that are to be machined on both ends or sides usually require two chuckings. However, the casting shown in Fig. 47 (*a*) is machined in one chucking to the following extent: The hole is bored and reamed, the hub is faced at both ends, one end of the bore is counterbored for the thread, and the counterbore is undercut to give a clearance for the threading tool; also the edges of the ring groove at the threaded end are chamfered.

63. The first operation is to rough-bore and counterbore the hole by the two similar tools *a* and *b* held in the same bar on side *1* of the turret, as shown in Fig. 47 (*b*). The bar on side *2* is next used to face the rear end of the hub with the tool *c*, and to undercut the counterbore with the tool *d*. The same turret motion that performs these two operations also faces the front end of the hub with the tool *e* clamped in side *2*. The tool *f* on the third side of the turret finishes the counterbore to the correct threading diameter. On side *4* a bar with two similar tools *g* and *h*, which are located in line, finish-bore the hole, and at the same time the double cutter *i* chamfers the corners of the annular groove. The threading tool *j* is on the fifth side, and the final finishing of the bore to 4 inches in diameter is made by the reamer *k* on side *6*.

64. Double-Spindle Shaft Work.—An example of the work done on the double-spindle turret lathe in two chuckings is shown in Figs. 48 and 49. Two forged-steel cam-shafts *a* for an automobile engine are given four identical inside opera-



5 3/8"
45°
5/32"
3/32"
1/16"
5/16"
4" ±.001 Dia.
4 13/16" Dia.
8 11/16" Dia.
8600 .005 Dia.
(a)
k
j
a
b
i
g
h
c
d
e
f
1
2
3
4
5
6
(b)

FIG. 47

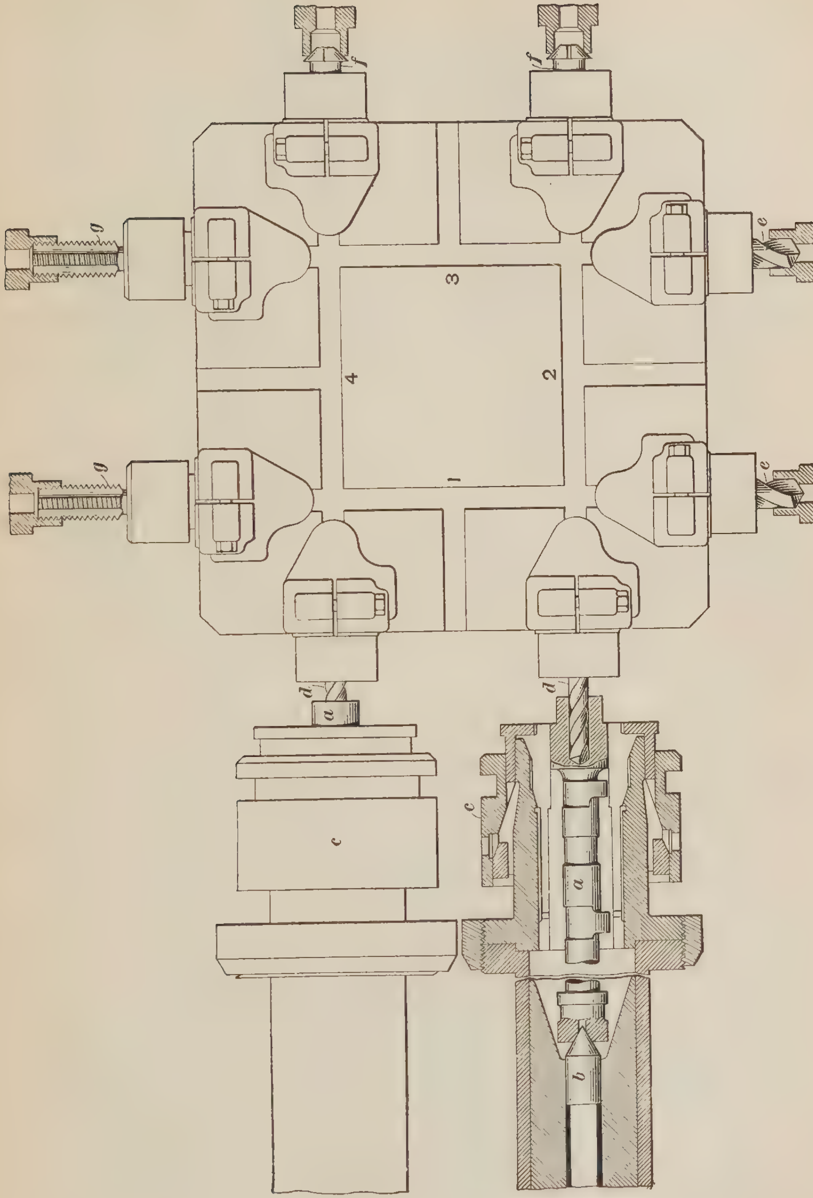


Fig. 48

tions on each end after their journals and cams have been finished either by turning or grinding or both.

For the first setting, Fig. 48, the inner end of the shaft is held on a spindle center *b* and the outer end is gripped by a hand-operated collet chuck *c*. The first operation is to make a small hole to the required clearance depth by the short drill *d* on side *1* of the turret as shown. The larger drill *e* on the second side of the turret is then used to counterbore the hole to the threading diameter and depth. The tool *f* on side *3* is used to chamfer the hole so that the bottoming tap *g* on side *4* will automatically center and produce a clean thread.

For the second setting the shaft is reversed as shown in Fig. 49. Its inner end is held on the conical center *h* and its outer end is covered by a split bushing *i* so that it can be gripped in the collet chuck c_1. A small hole is then drilled in the shaft to the proper depth to give clearance to the threading operation and to conduct oil to the bearing. The hole is then enlarged or counterbored by the drill e_1 on side *2* of the turret. The threading is done by the tapered pipe tap g_1 on side *3*, and the edge of the hole is smoothed by chamfering with the tool f_1 on side *4*.

65. Machining Cast-Iron Gear Blank.—The casting *a*, Figs. 50 and 51, from which a gear is to be made, requires finishing on the circumference and both sides of the rim, in the bore, and on both ends of the hub. Furthermore, all the surfaces must be made true with the bore. Two chuckings are necessary. The casting is first chucked with hard jaws *b* on the inside of the rim and with chuck jacks *c* between the jaws, as in Fig. 50. The hard jaws are needed to grip the rough unfinished surface of the casting, and the jacks give a solid side support to prevent its springing from the heavy pressure of the turret tools. The chuck jacks also space the castings equally from the chuck face so that the turret stops can be set closely to the dimensions required on the finished work.

The roughing cuts are taken in order on the side surfaces *d*, *e*, and *f* by the tool *g* in the square turret post *h*. When the skin of a casting or a forging is removed the piece is liable to

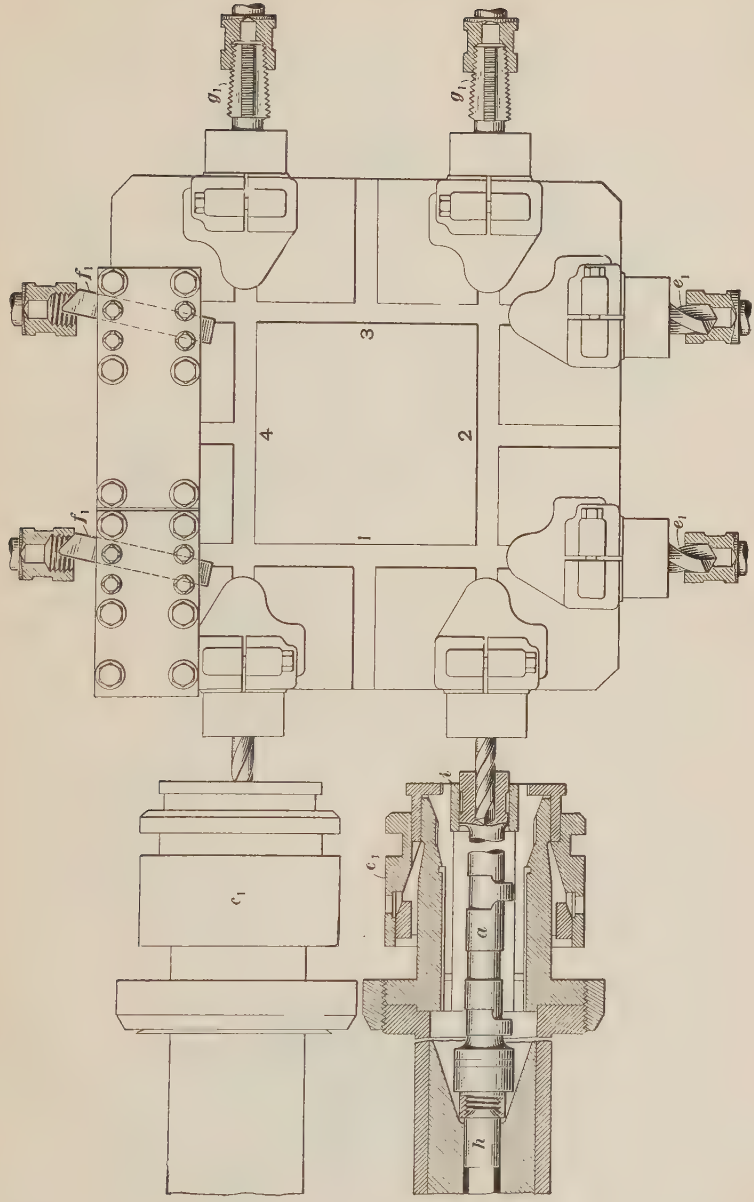


Fig. 49

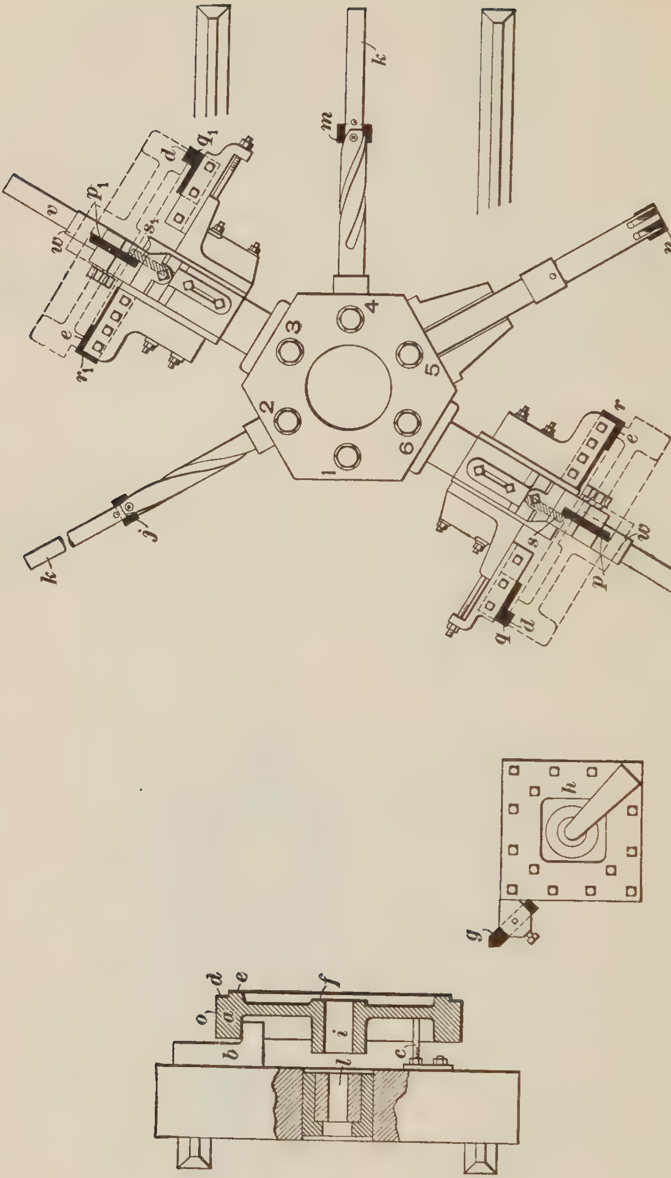


FIG. 50

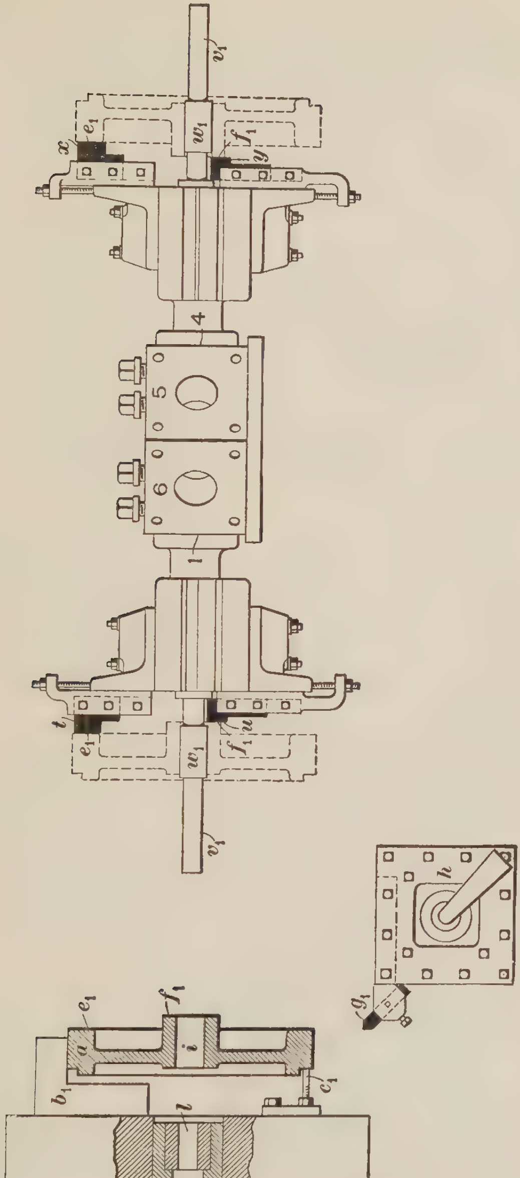


Fig. 51

warp. Therefore, semifinishing cuts are often necessary in order to square up the surfaces ready for the final, or finishing, cut. Next, rough-bore the hub *i* with the boring bar *j* in side *2* of the hexagon turret. The pilot *k* is supported in the bushing *l* centered in the chuck. The hub is finish-bored by the boring bar *m* in side *4*, and finished to exact size by the helical reamer *n* in side *5*.

The rim *o* is rough-turned by the tool *g* in the tool post *h* and semifinished by the tool *p* in the top arm of the four-arm tool head on side *6*. The tools *q*, *r*, and *s* are also in this head and are used to semifinish the faces *d*, *e*, and *f*, respectively. The pilot *v* of the tool head has a sleeve *w* that fits the bore of the gear and centers and squares the tools with the bore. Finally, the tool head on side *3* is used and the tools p_1, q_1, r_1, and s_1 finish the first chucking operations, which require about $7\frac{1}{2}$ minutes.

66. The casting is reversed and chucked with soft jaws b_1 on the finished rim and with chuck-jack back supports c_1, as shown in Fig. 51. Soft jaws are used to prevent marring the rim surface. The sides e_1 and f_1 are rough-faced by the tool g_1 in the square post turret *h*. The semifinishing of these two surfaces is then done by the tools *t* and *u* in the top and bottom arms of the tool head on side *1*. The pivot v_1 on this head enters the bushing *l* in the chuck, and has also a sleeve w_1 that fits the finished bore *i* of the gear and thus centers and squares the tool head with the bore. Finally the surfaces e_1 and f_1 are finished by the tools *x* and *y* in the top and bottom arms of the facing head on side *4*, as shown. The second chucking operations require about $3\frac{1}{4}$ minutes.

67. Machining Cast-Iron Flywheel.—In Figs. 52, 53, 54, and 55 are shown the operations necessary for machining a cast-iron flywheel *a* in two chuckings. The hollow side of the wheel is operated on first, as shown in Fig. 52. The casting is set in the chuck and the hub *b*, web *c*, and rim surfaces *d*, *e*, and *f* are given their roughing cuts by the tools *h* and *i* in the square tool post *g*.

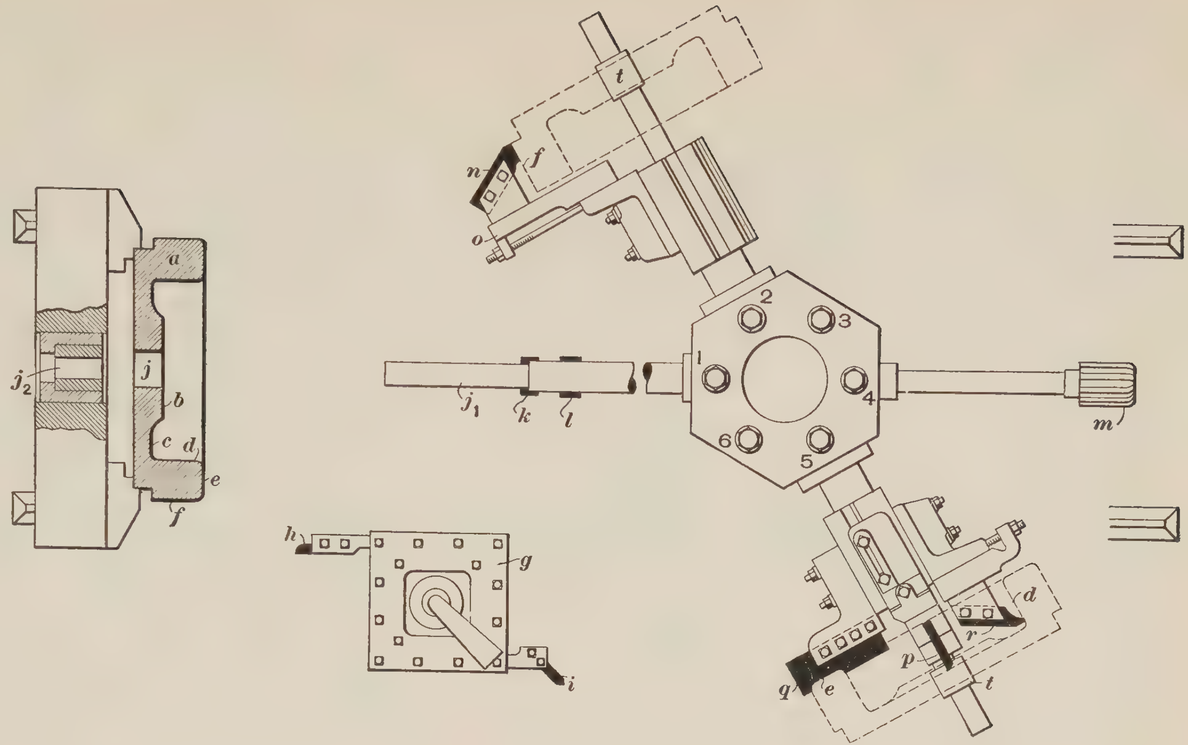


FIG. 52

The hole j is next rough-bored and finish-bored by the tools k and l respectively in the boring bar on face *1* of the turret, and followed by the reamer m on face *4*. The rim f is finished by the tool n in the facing head o on face *2* of the turret. The other four finishing operations are performed by tools held in the head on face *5* of the turret. The positions of these tools are shown at p, q, and r in Figs. 52 and 53. The turning tool p is mounted in the top arm of the facing head and finishes the surface f. The forming tool q is held in the

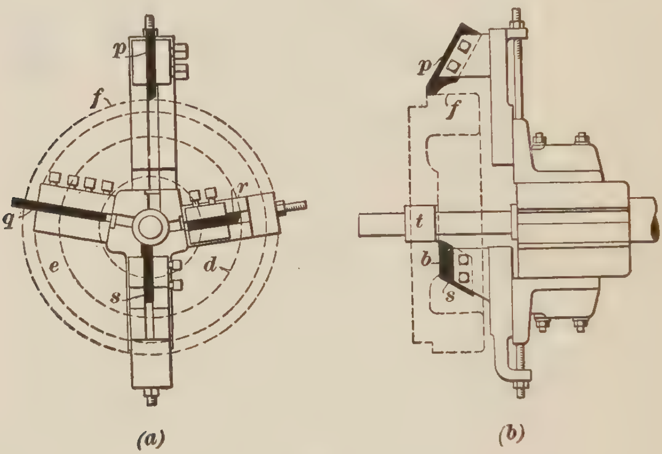


Fig. 53

rear arm and finishes the side e of the rim. The tool r is mounted in the front arm and finishes the rim bore d, and the tool s is in the bottom arm and faces the hub b.

The boring bar has a pilot j_1 that enters a bushing j_2 in the lathe chuck so as to center and steady the bar. The heads on faces *2* and *5* are provided with pilot bushings t that fit the bore j, thus insuring that all the surfaces will be finished true with the bore j. The total time required for the first chucking operations is about 20 minutes.

68. The flywheel is next reversed and chucked as shown in Fig. 54. Besides being clamped by the jaws, back supports, or jacks, are placed between the jaws as shown at u. The counterbore v is formed and the web surface w is rough-faced

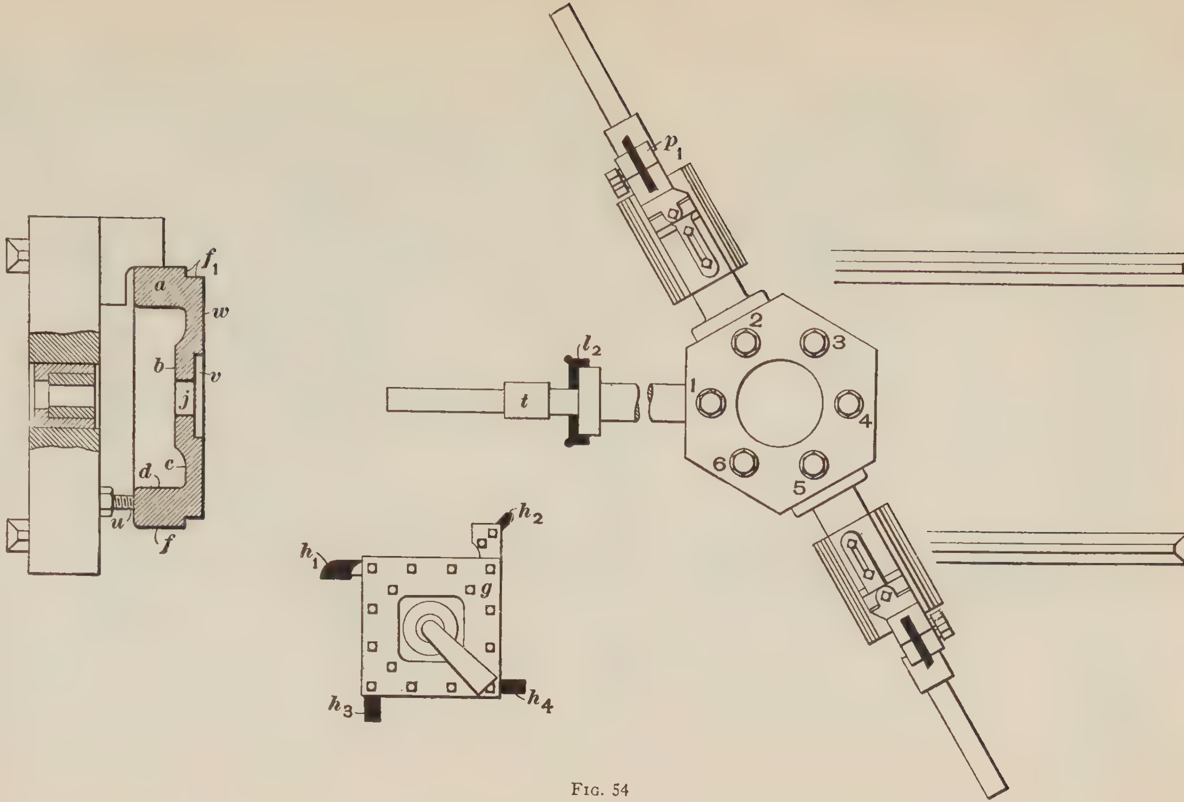


FIG. 54

by the tool h_1 in the square tool post g. The surfaces f_1 are turned by the tool h_2, and the bottom of the counterbore v is faced by the tool h_3. The tool head on side *2* of the turret

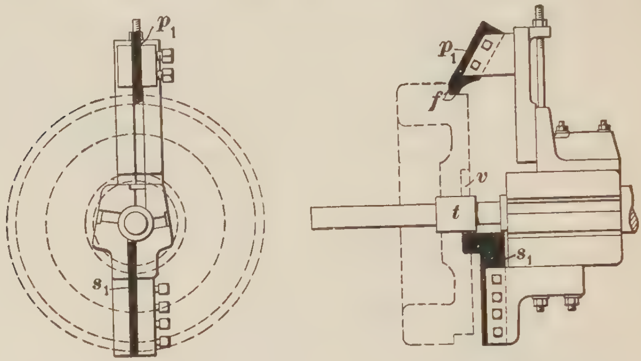


FIG. 55

is then used. This head has two arms as shown in detail in Fig. 55. The one at the top holds the tool p_1 for taking the second roughing cut over the notched surfaces f_1, while the tool s_1, which is held in the lower arm, is used for the second cut on the counterbore v. The tool l_2 on the face *1* of the turret, Fig. 54, is used to make the second finishing cut on the side of the counterbore, and to form a rounded corner in the bottom. The web w is finished with the tool h_4 in the tool post g. The final finishing of the counterbore is done with the cutters held in the tool head on the side *5*, which are similar in form to those on face *2*. The time required for the second chucking operations is about fifteen minutes.

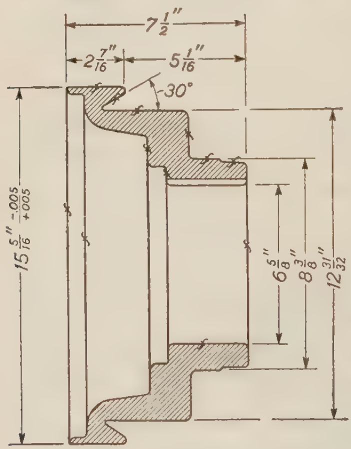


FIG. 56

69. Machining Commutator Shell.—For machining the commutator shell shown in Fig. 56, and at *A* in Fig. 57, two

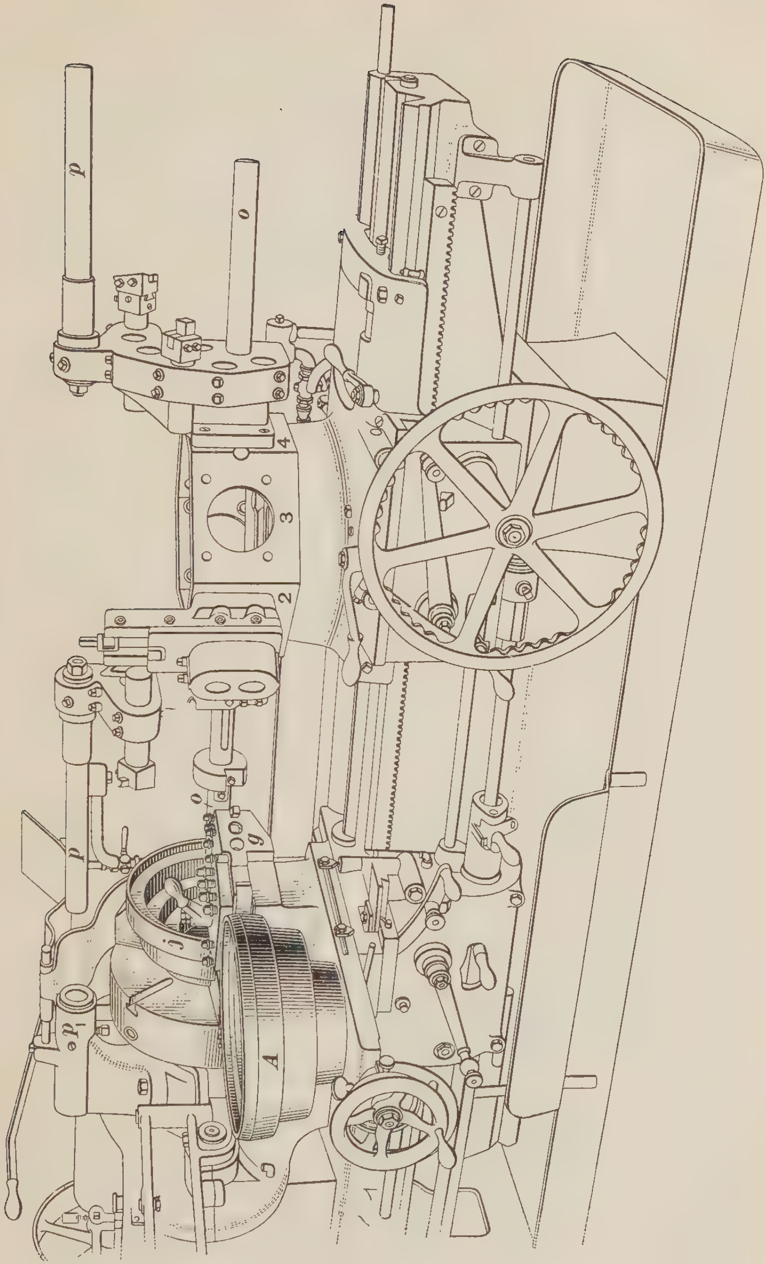


Fig. 57

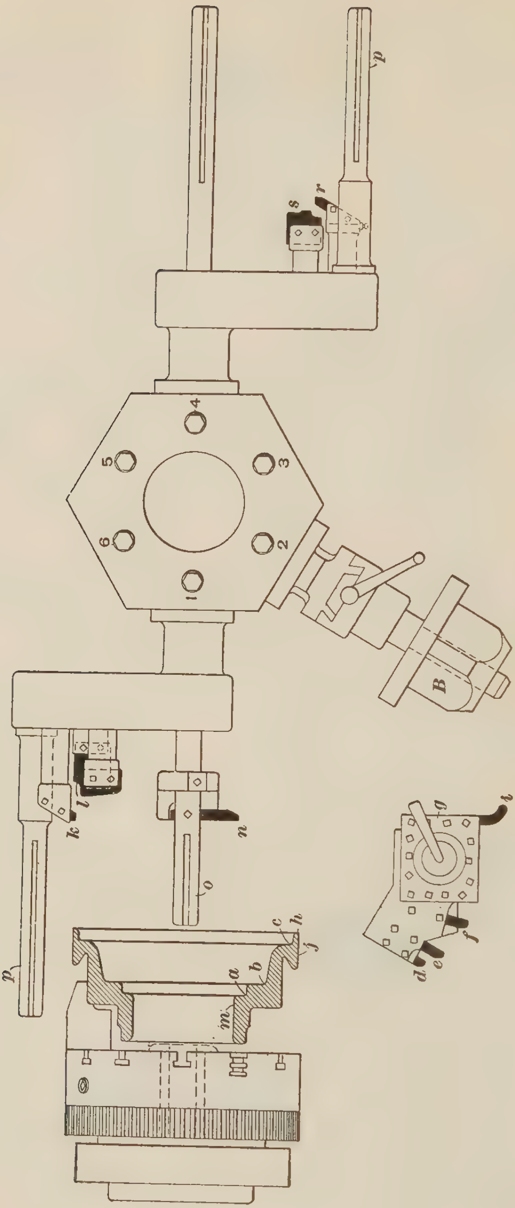


Fig. 58

chuckings are required. This example is a pressed-steel forging that must be finished all over except on a small part of the bellmouth surface. (See the marks *f* denoting finish.) The outside diameter of the largest ring must be made quite exact, permitting a variation either above or below $15\frac{5}{16}$ inches, of only .005 inch. The groove cut under the inner side of the large ring is to be chamfered 30 degrees to the center line as shown.

70. First Chucking of Commutator Shell.—The first chucking operation is shown in Figs. 57 and 58. The small end of the forging is held in a three-jaw chuck so that the hub can be bored, and all the inside surfaces together with the periphery and edge of the largest ring can be machined. The roughing cuts on the surfaces *a*, *b*, and *c* are made with the tools *d*, *e*, and *f*, respectively, held in the square turret tool post *g* on the cross-slide. The edge *h* of the rim is then rough-faced with the tool *i* in the tool post. The outer surface *j* is turned with the tool *k*, and the edge *h* is rounded with the tool *l*, both tools located in the tool head in face *1* of the turret. The hub surface *m* is then bored with the tool *n* held in the boring bar located in the same tool head. The boring bar has a pilot *o* that extends into a bushing in the chuck for the purpose of giving a rigid support to the bar.

After completing these roughing operations, the finishing tools *r* and *s* in the tool head on face *4* of the turret are used to finish the surface *j* and the edge *h* of the forging so that when it is reversed for the second chucking it can be held true in the chuck by means of these surfaces. The tool heads *1* and *4* have pilot supports *p* that enter a hole in the bracket p_1 on the headstock. The total time required for the operations given above, including the loading of the lathe chuck by means of the work holder is about $12\frac{1}{2}$ minutes.

71. Second Chucking of Commutator Shell. — After unloading the work finished in the first chucking operations described in the previous article, the forging is reversed and the large end set in the chuck as shown in Figs. 59 and 60, by means of the loading head *B* on face *2* of the turret. The

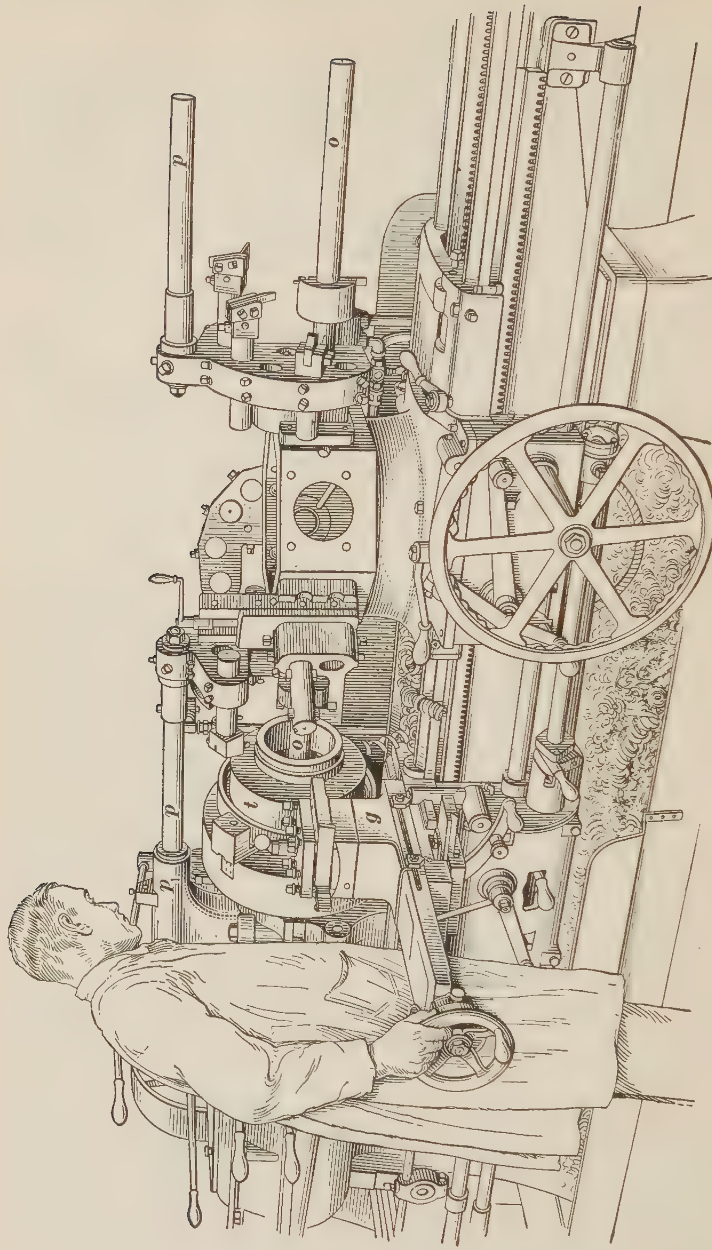
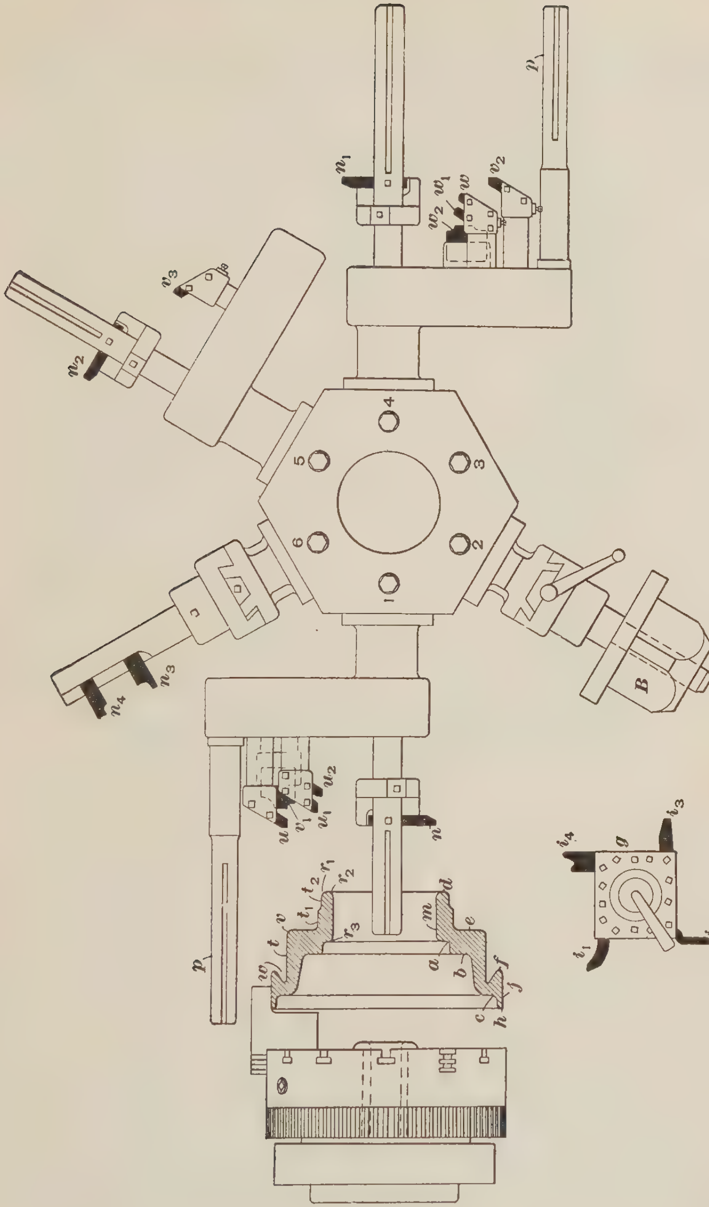
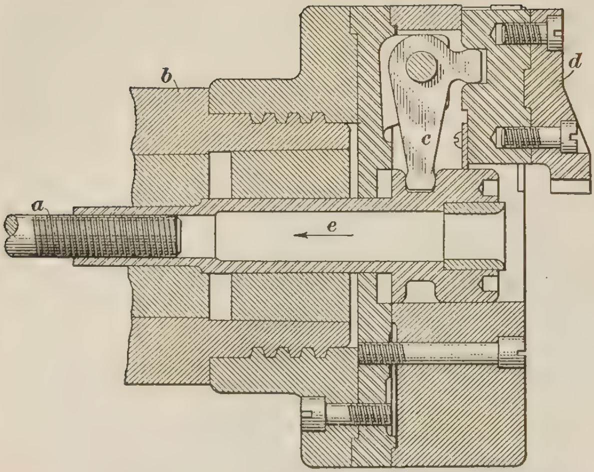


Fig. 59

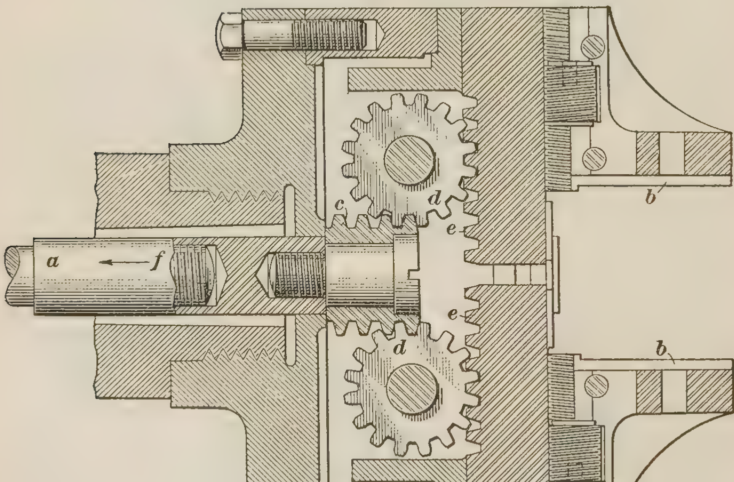


n_1
w_1
w
v_2
p
w_2
v_3
n_2
4
5
3
6
2
1
n_3
n_4
B
u_2
u
v_1
u_1
n
t
v
t_1
t_2
r_1
r_2
r_3
d
m
e
a
b
f
j
c
h
g
i_1
i_2
i_3
i_4

FIG. 60



(a)



(b)

Fig. 38

71. Air-Operated Chuck.—The operating mechanism of one jaw of an air-operated three-jaw chuck is shown in Fig. 38 (*a*). Air pressure is exerted on a piston in a double-acting cylinder fastened to the headstock frame at the outer end of the spindle. The movement of the air piston is transmitted to the chuck by means of the piston rod *a* that reaches through the lathe spindle *b* to the radial arm of a bell-crank *c* inside the chuck. The horizontal arm of the bell-crank engages the back of the jaw *d*. Each jaw has a bell-crank arranged like the one shown at *c*.

When the jaws are to be closed, compressed air is admitted to the end of the cylinder that will pull the rod *a* outwards in the direction of the arrow *e*. The air pressure must be kept on while the work is being machined. Releasing the air lets the work drop out of the chuck. In most cases the work can be changed without stopping the machine.

A two-jaw air chuck is shown in Fig. 38 (*b*). The motion of the piston rod *a* is transmitted to the jaws *b* by a circular rack *c* attached to the end of the rod and engaging two pinions *d*, which mesh with a rack *e* on the back of each jaw. The jaws are closed by the rod *a* pulling in the direction of the arrow *f*.

72. Magnetic Chuck.—In Fig. 39 (*a*) is shown one form of magnetic chuck, and in (*b*) is seen the inside of the chuck body, with the back cover-plate removed. The work is held against the face of the chuck by the magnetizing force of a number of poles *a* inside the chuck. These poles are energized by an electric current through coils *b* surrounding them. The poles are spaced so as to insure uniform holding power over the face of the chuck. The current is led from a direct-current supply to two brushes in the holder *c*, which bear against two contact rings *d* and *e* at the back of the chuck, and insulated from each other as shown in (*c*). The ends of the coils *b* are connected to the rings *d* and *e*, and thus by closing a switch the chuck is instantly magnetized. When the current is turned off the chuck becomes demagnetized, and the work either drops off or it can be easily detached from the face of the chuck.

of the rim with the tool *c* and the outside *d* of the hub with the tool *e*, bore the hub with the tool *f*, and chamfer its edges with the tool *g*. In the second turret position the radial surfaces *h*, *i*, and *j* are faced with the tools *k*, *l*, and *m*, respectively, and the rim *n* with the tool *o*; and in the third position the face *i* of the hub is finished with the tool *p*.

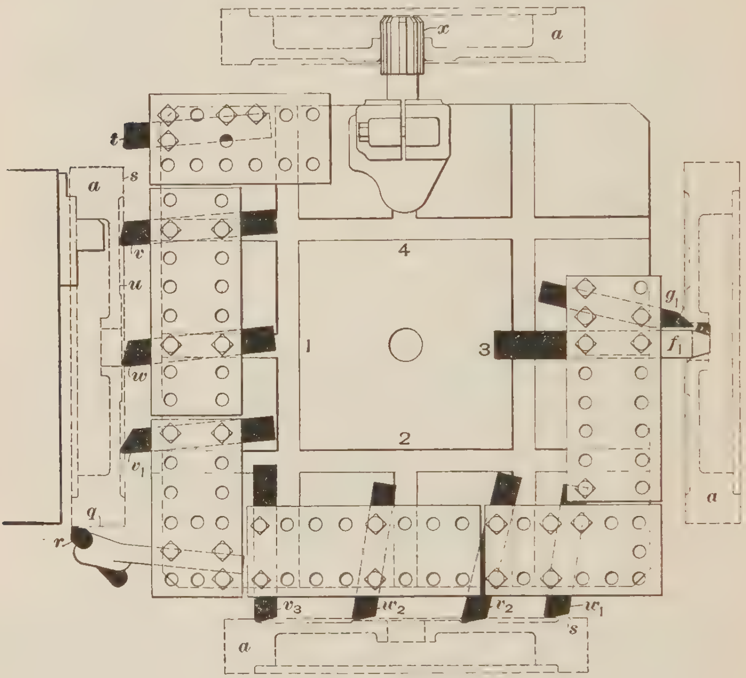


FIG. 63

For the second mounting the forging *a* is reversed and chucked on the inside, as shown in Fig. 63. The outside *q* of the rim is rough-turned with the tool *r*, and the radial surfaces *s* and *u*, and the hub are rough-faced with the tools *t*, *v*, and *w*. In the second position of the turret the radial surfaces are finished with the tools w_1, w_2, v_2, and v_3. In the third position the hub is finish-bored with the tool f_1, and the edge of the hole chamfered with the tool g_1. In the fourth position the bore is finished to its accurate diameter with the reamer *x*.

For the third set of operations the flywheel a is held on a mandrel y, shown in Fig. 64, with its hollow side next to the turret, and the rough-turned surfaces finished true with the bore. The mandrel fits the finished bore of the wheel and the clamping is done by a nut and washer against the finished face of the hub. The wheel is driven by a pin y_1. In the first

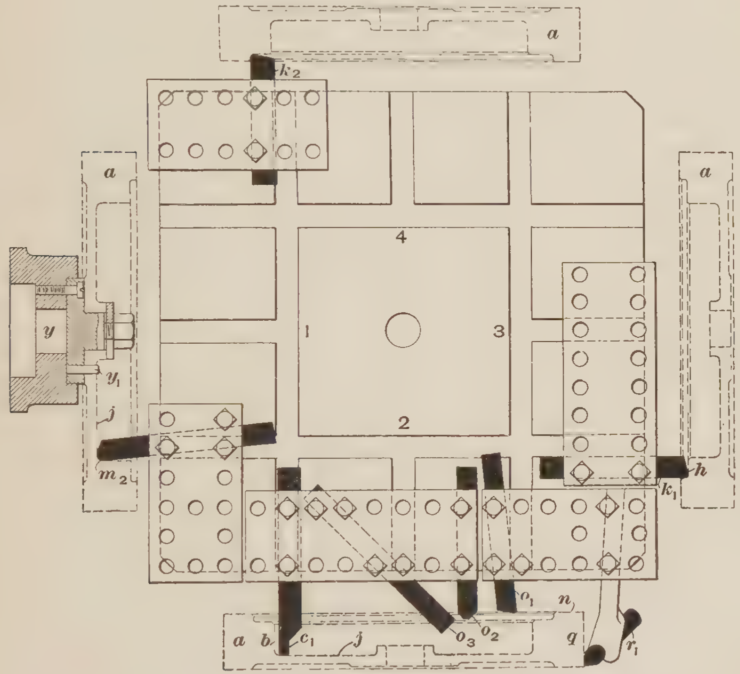


FIG. 64

position of the turret the tool m_2 finish-bores the inside of the rim. In the second position the outside rim surface q is finish-turned by the tool r_1, and the radial surfaces n and j finish-faced by the tools o_1 and c_1; also, the inner corners are chamfered by the tools o_2 and o_3. In the third position of the turret the radial surface h is finish-faced by the tool k_1; and in the fourth position the recess inside the rim is accurately sized by the tool k_2.